



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

### Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

### About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

**HARVARD COLLEGE  
LIBRARY**



**The  
Charles Motley Clark  
Memorial**













*Illustration of the interior of the building, showing the large hall and the various rooms.*

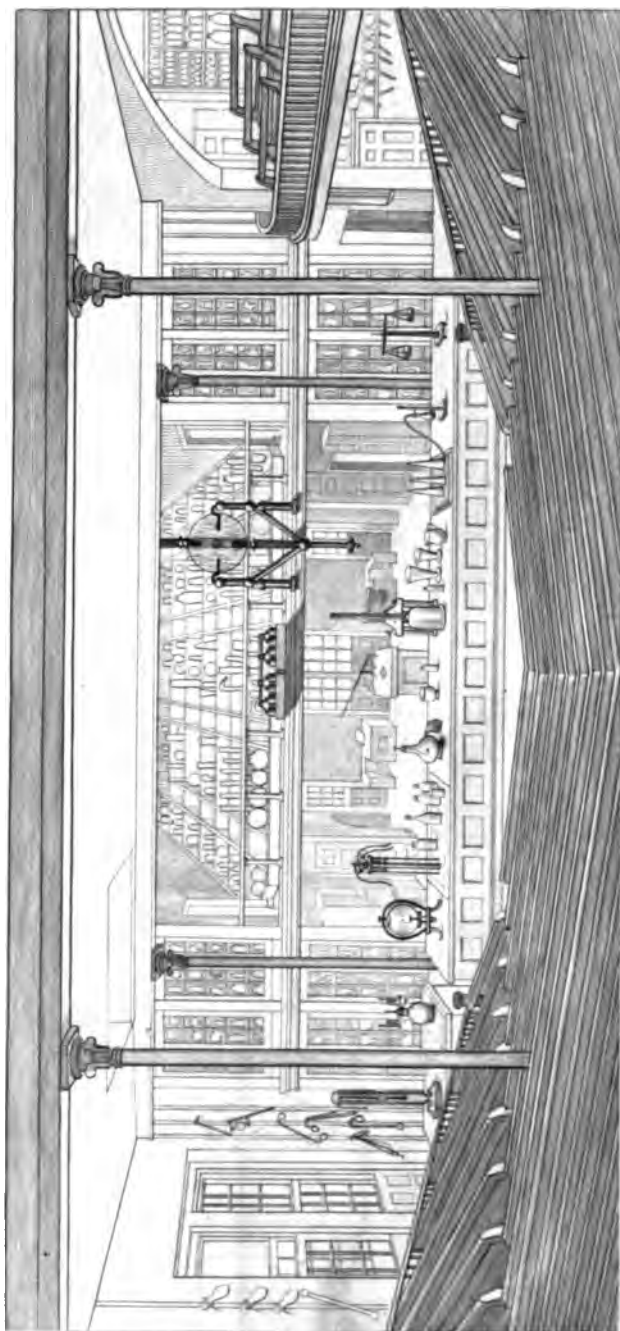


ILLUSTRATION OF THE INTERIOR OF THE BUILDING, SHOWING THE LARGE HALL AND THE VARIOUS ROOMS.

✓

A  
"COMPENDIUM  
OF THE  
COURSE OF CHEMICAL INSTRUCTION,"  
IN THE  
MEDICAL DEPARTMENT  
OF THE  
UNIVERSITY OF PENNSYLVANIA.

BY  
ROBERT HARE, M.D.  
PROFESSOR OF CHEMISTRY.

---

IN TWO PARTS.

---

PART I.

COMPRISING THE  
CHEMISTRY OF HEAT AND LIGHT, AND THAT OF INORGANIC  
SUBSTANCES, USUALLY CALLED INORGANIC CHEMISTRY.

---

FOURTH EDITION.  
WITH AMENDMENTS AND ADDITIONS.

---

PHILADELPHIA:  
J. G. AUNER, No. 343 MARKET STREET.  
John C. Clark, Printer.

1840.

(98)

Chem 428.40

1874, Oct. 6.

Gift of  
Edward H. Clarke, M.D.  
of Boston,  
(#. 2. 1841.)



## PREFACE

### TO THE FIRST EDITION.

---

WHERE a subject cannot be followed by a reader without *study*, it would seem unreasonable to expect that, without some assistance, it should be followed at a lecture. Under this impression, from the time that I became a lecturer, I applied myself so to improve and multiply the means and methods of experimental illustration, as to render manipulation easier, and the result more interesting and instructive.

But notwithstanding all my efforts, there remained obstacles to be surmounted. However striking might be the experimental illustration of a property or principle, the rationale might be incomprehensible to a majority of my class, unless an opportunity for studying it were afforded them.

Again, some of my contrivances, which greatly facilitated my experiments, were too complex to be understood without a minuteness of explanation, which, even if it were useful and agreeable to some of my hearers, might be useless and irksome to others; and to such minutiae I have not deemed it expedient to exact attention.

A chemical class, in a medical school, usually consists of individuals, who differ widely with respect to their taste for chemistry, and in opinion as to the extent to which it may be practicable or expedient for them to learn it. There is also much disparity in the opportunities which they may have enjoyed, of acquiring some knowledge of this science, and of others which are subsidiary to its explanation. Hence a lecturer may expatiate too much for one portion of his auditors, and yet be too concise for another portion. While to the adept he may often appear trite, to the novice he may as often appear abstruse.

Some pupils, actuated by a laudable curiosity, under circumstances permitting its indulgence, may desire an accurate knowledge of the apparatus by which my experimental illustrations are facilitated: other pupils may feel themselves justified, perhaps necessitated, not to occupy their time with the acquisition of any knowledge which is not indispensable to graduation.

After some years' experience of the difficulties abovementioned, I came to the conclusion that the time spent in the lecture room might be rendered much more profitable, if students could be previously apprized of the chain

of ideas, or the apparatus and experiments, to be subjected to attention at each lecture; especially as the memory might afterwards be refreshed by the same means. In consequence of this conviction, the minutes of my course of instruction were printed; and subsequently a work, comprising engravings and descriptions of the larger portion of such of my apparatus and experiments, as could in this way be advantageously elucidated. Encouraged by the success of my plan, I am now preparing an edition which will be still more extensive. The work thus expanded, I have entitled "A Compendium of the Course of Chemical Instruction in the Medical School," &c.

There will be much matter in the Compendium, respecting which I shall not question candidates at the examination for degrees. With the *essence* of the larger part, I shall undoubtedly expect them to be acquainted; but other portions have been introduced, that I may not be obliged to dwell upon them in my lectures, and that attention to them may be optional on the part of the students. To designate the portion of the work, respecting which candidates for degrees will not be questioned, I have had it printed in a smaller type, excepting where it was too much blended with subjects of primary importance to be separated. I wish it, however, to be understood, that I shall expect attention to the parts thus distinguished, so far as they may be necessary to a comprehension of the rest. Thus, although I do not deem it to be a part of my duty to question a pupil on pneumatics, I shall expect him to understand the influence of atmospheric pressure upon chemical reaction, and in pneumato-chemical operations.

One great and almost self-evident advantage, resulting from my undertaking, I have yet to mention; I allude to the instruction which students may derive from the Compendium, either before or subsequently to their attendance on my lectures, and especially during the period which intervenes between their first and second course.

1828

## PREFACE

### TO THE FOURTH EDITION.

---

THE suggestions, which were made in the Preface to the first edition of the Compendium, respecting the necessity of an appropriate text book, to aid and extend the instruction afforded by the course of chemical lectures, delivered in the Medical Department of the University of Pennsylvania, have acquired additional force since that Preface was written. During the twelve intervening years the boundaries of those portions of human knowledge over which Chemistry has established a rightful domain, have undergone an extension commensurate with the time. It is, of course, proportionably more difficult to do justice to the whole of the wonderful region comprised within those boundaries in sixty lectures delivered within four months. Formerly, the attention of the student was alternately claimed by six professors; but lately, the claims of a seventh professor have been added to those previously established. Nevertheless, I am under the impression, that with the assistance which my text books are competent to afford, my course of lectures, brief as it is, may be more serviceable to a student *who makes due use of those text books*, than it could prove, were its duration doubled, without being associated with treatises made expressly for the purpose of amplifying the information partially afforded by my lectures, or of remedying the inevitable omissions.

Having been prevented by indisposition from commencing this work as early as expedient, I am under the necessity of issuing that part which relates to Caloric, Light, and Inorganic Chemistry first. Dynamic Electricity, comprising Galvanism or Voltaic Electricity, and Electro-magnetism, having been already issued, I shall in the next place republish my Treatise on Mechanical Electricity. Then to complete the new edition of my text books, only Organic Chemistry will remain to be reprinted. On this branch I hope to furnish a treatise before I reach that part of my course of lectures, in which it becomes the object of attention.

I am in hopes that numbering the paragraphs, an excellent expedient resorted to by me for the first time in this edition, will be found advantageous to the reader, by rendering references from one part of the work to another less inconvenient, and consequently more frequent.



# CONTENTS.

	Page
<b>INTRODUCTION.</b>	
Definition of Natural Philosophy, Chemistry, and Physiology	1
Of Chemical reaction	2
Of repulsive reaction, or repulsion	2
<b>I. CALORIC.</b>	
Experimental proofs of a material cause of calorific repulsion	3
Expansion	6
Expansion of solids	6
Expansion of liquids	8
Expansion of æriform fluids	10
Thermometers	10
Modification of the effects of caloric by atmospheric pressure	14
Capacities for heat, or specific heat	44
Slow communication of heat, comprising the conducting process and circulation	47
Quick communication of heat, or radiation	52
Means of producing heat, or rendering caloric sensible	57
Means of producing cold, or rendering caloric latent	68
States in which caloric exists in nature	74
II. Light	75
Sources of light	76
Heating, illuminating, and chemical properties of the rays	78
Polarization of light	80
<b>PONDERABLE MATTER.</b>	
<b>DETAILS GENERAL PROPERTIES OF PONDERABLE MATTER AND THE MEANS</b>	
<b>OF ASCERTAINING OR INVESTIGATING THEM</b>	
Section I. Chemical attraction	83
Attraction of aggregation, or cohesion	83
Crystallization	84
Chemical affinity, or heterogeneous attraction	89
Section II. Definite proportions	93
Tables of chemical equivalents	94
Atomic theory	95
Chemical symbols	96
Atomic weights and symbols of the simple substances	97
Section III. Specific gravity	98
Definition and discovery of the æriform fluids called gases	105
<b>ORGANIC CHEMISTRY; OR CHEMISTRY OF INORGANIC SUBSTANCES.</b>	
Individual ponderable elements	110
<b>SECTION ELEMENTS</b>	110
I. Oxygen	110
II. Chlorine	117
Compounds of chlorine with oxygen	123
Hypochlorous acid, or protoxide of chlorine	124

	Euchlorine, or impure chlorous acid	-	-	-
	Chloric acid	-	-	-
	Oxychloric, or perchloric acid	-	-	-
III.	Bromine	-	-	-
	Compounds of bromine with oxygen and chlorine	-	-	-
	Bromic acid	-	-	-
	Chloride of bromine	-	-	-
IV.	Iodine	-	-	-
	Compounds of iodine with oxygen	-	-	-
	Iodic, hyperiodic, and iodous acid	-	-	-
	Chlorides and bromides of iodine	-	-	-
V.	Fluorine	-	-	-
VI.	Sulphur	-	-	-
	Compounds of sulphur with oxygen	-	-	-
	Hyposulphurous acid	-	-	-
	Sulphurous acid	-	-	-
	Hyposulphuric acid	-	-	-
	Sulphuric acid	-	-	-
	Chlorides, bromide, and iodide of sulphur	-	-	-
VII.	Selenium	-	-	-
	Compounds of selenium with oxygen	-	-	-
VIII.	Tellurium	-	-	-
RADICALS		-	-	-
NON-METALLIC RADICALS		-	-	-
SECT. I.	Hydrogen	-	-	-
	Compounds of hydrogen with oxygen	-	-	-
	Water	-	-	-
	Deutoxide or bioxide of hydrogen	-	-	-
	Compound of hydrogen with chlorine	-	-	-
	Chlorohydric or muriatic acid gas	-	-	-
	Old theory of the nature of chlorine and chlorohydric acid	-	-	-
	Bromohydric acid	-	-	-
	Iodohydric acid	-	-	-
	Compounds of hydrogen with sulphur	-	-	-
	Sulphydric acid, or sulphuretted hydrogen	-	-	-
	Polysulphide of hydrogen	-	-	-
	Compounds of hydrogen with selenium and tellurium	-	-	-
	Selenohydric acid, or selenuretted hydrogen	-	-	-
	Tellurhydric acid, or telluretted hydrogen	-	-	-
II.	Nitrogen or azote	-	-	-
	Atmospheric air	-	-	-
	Chemical compounds of nitrogen with oxygen	-	-	-
	Protoxide of nitrogen, or nitrous oxide	-	-	-
	Nitric oxide, or nitrous air	-	-	-
	Hyponitrous acid	-	-	-
	Nitrous acid	-	-	-
	Theory of volumes	-	-	-
	Nitric acid	-	-	-
	Nitroso-nitric acid	-	-	-
	Compounds of nitrogen with chlorine and iodine	-	-	-
	Some points of chemical theory	-	-	-
	Theories of combustion	-	-	-
	Influence of the habitudes of chemical agents with the	-	-	-
	Voltaic series, on classification and nomenclature	-	-	-
	Methods of distinguishing degrees of oxidizement, de-	-	-	-
	rived from the school of Lavoisier	-	-	-
	Origin of the erroneous idea of an acidifying principle	-	-	-
	Acidity	-	-	-
	Alkalinity	-	-	-
	Compounds of nitrogen with hydrogen	-	-	-

# CONTENTS.

ix

	Page
Ammonia, or the volatile alkali	204
Ammonium	208
III. Phosphorus	211
Compounds of phosphorus with oxygen	214
Oxide of phosphorus	215
Hypophosphorous acid	215
Phosphorous acid	215
Phosphoric acid	216
Chlorides of phosphorus	217
Bromides and iodides of phosphorus	217
Sulphides and selenides of phosphorus	217
Compounds of phosphorus with hydrogen	218
Protosphophuretted hydrogen	218
Perphosphuretted hydrogen	218
IV Carbon	220
Compounds of carbon with oxygen	224
Carbonic oxide	224
Carbonic acid	225
Oxalic acid	231
Mellitic acid	232
Croconic acid	232
Compounds of carbon with oxygen and chlorine	232
Chloral	232
Chloroxycarbonic acid	233
Chlorides of carbon	233
Bromide of carbon	233
Iodides of carbon	233
Sulphocarbonic acid, or bisulphide of carbon	234
Compounds of carbon with hydrogen	234
Light carburetted hydrogen, or fire damp	236
Safety lamp	236
Deutocarbohydrogen, or olefiant gas	237
Certain gaseous compounds formed by igniting gaseous elements of water with olefiant gas, &c.	238
Other varieties of carbohydrogen	240
B-carburet of hydrogen	240
Naphthaline	240
Compounds of carbon with chlorine and hydrogen	241
Compound of carbon with nitrogen	241
Bicarburet of nitrogen, or cyanogen	241
Nomenclature of the compounds of cyanogen	242
Cyanic, cyanuric, and fulminic acid	243
Chlorides, bromides, and iodides of cyanogen	245
Sulphocyanogen	245
Sulphocyanhydric acid	245
Cyanhydric or prussic acid	246
V Boron	249
Compound of boron with oxygen	250
Boric or boracic acid	250
Chloride of boron	251
VI. Silicon	251
Compound of silicon with oxygen	253
Silica, or silicic acid	253
Glass	254
Compounds of fluorine with hydrogen, boron, and silicon	255
Fluohydric acid	256
Fluoboric acid	256
Fluosilicic acid	257
Reaction of fluohydric acid with fluoboric and fluosilicic acid	258

<b>SECT. VII. Zirconion</b>	-	-	-	-	-	-	-	-
<b>METALLIC RADICALS</b>	-	-	-	-	-	-	-	-
<b>METALS OF THE EARTHS PROPER</b>	-	-	-	-	-	-	-	-
<b>SECT. I. Aluminium</b>	-	-	-	-	-	-	-	-
Alumina	-	-	-	-	-	-	-	-
Chloride of aluminium	-	-	-	-	-	-	-	-
<b>II. Glucinium</b>	-	-	-	-	-	-	-	-
Glucina	-	-	-	-	-	-	-	-
<b>III. Yttrium</b>	-	-	-	-	-	-	-	-
Yttria	-	-	-	-	-	-	-	-
<b>IV. Thorium</b>	-	-	-	-	-	-	-	-
Thorina	-	-	-	-	-	-	-	-
<b>METALS OF THE ALKALINE EARTHS</b>	-	-	-	-	-	-	-	-
<b>SECT. I. Magnesium</b>	-	-	-	-	-	-	-	-
Magnesia	-	-	-	-	-	-	-	-
<b>II. Calcium, barium and strontium</b>	-	-	-	-	-	-	-	-
Evolution of calcium, barium and strontium	-	-	-	-	-	-	-	-
<b>III. Lime, or calcia, the oxide of calcium</b>	-	-	-	-	-	-	-	-
Baryta	-	-	-	-	-	-	-	-
Strontia	-	-	-	-	-	-	-	-
Peroxides or bioxides of barium and strontium	-	-	-	-	-	-	-	-
<b>METALS OF THE ALKALIES, OR ALKALIFIABLE METALS</b>	-	-	-	-	-	-	-	-
<b>SECT. I. Potassium</b>	-	-	-	-	-	-	-	-
<b>II. Sodium</b>	-	-	-	-	-	-	-	-
Potash or potassa, and soda	-	-	-	-	-	-	-	-
Peroxides and suboxides of potassium and sodium	-	-	-	-	-	-	-	-
<b>III. Lithium</b>	-	-	-	-	-	-	-	-
Lithia	-	-	-	-	-	-	-	-
Reaction of chlorine, bromine, iodine, fluorine, and cyanogen, with the metals of the earths and alkalies	-	-	-	-	-	-	-	-
Reaction of sulphur, selenium, and tellurium, with the metals of the earths and alkalies	-	-	-	-	-	-	-	-
<b>METALS PROPER</b>	-	-	-	-	-	-	-	-
<b>SECT. I. Gold</b>	-	-	-	-	-	-	-	-
Compounds of gold with oxygen	-	-	-	-	-	-	-	-
Compounds of gold with the halogen class	-	-	-	-	-	-	-	-
Compounds of gold with sulphur	-	-	-	-	-	-	-	-
<b>II. Platinum</b>	-	-	-	-	-	-	-	-
Compounds of platinum with oxygen	-	-	-	-	-	-	-	-
Compounds of platinum with the halogen class	-	-	-	-	-	-	-	-
Compounds of platinum with sulphur	-	-	-	-	-	-	-	-
Power of platinum and other metals in a divided or spongy form to induce chemical reaction	-	-	-	-	-	-	-	-
<b>III. Silver</b>	-	-	-	-	-	-	-	-
Compounds of silver with oxygen	-	-	-	-	-	-	-	-
Compounds of silver with the halogen class	-	-	-	-	-	-	-	-
Compounds of silver with sulphur	-	-	-	-	-	-	-	-
<b>IV. Mercury</b>	-	-	-	-	-	-	-	-
Compounds of mercury with oxygen	-	-	-	-	-	-	-	-
Reaction of acids with mercury and its oxides	-	-	-	-	-	-	-	-
Chlorides of mercury	-	-	-	-	-	-	-	-
Bromides, iodides, fluorides, and cyanides of mercury	-	-	-	-	-	-	-	-
Compounds of mercury with sulphur	-	-	-	-	-	-	-	-
Phosphurets of mercury	-	-	-	-	-	-	-	-
Combustion of mercury with chlorine	-	-	-	-	-	-	-	-
<b>V. Copper</b>	-	-	-	-	-	-	-	-
Compounds of copper with oxygen	-	-	-	-	-	-	-	-
Compounds of the oxides of copper with acetic acid	-	-	-	-	-	-	-	-
Compounds of copper with the halogen class	-	-	-	-	-	-	-	-
Compounds of copper with sulphur and selenium	-	-	-	-	-	-	-	-



# CONTENTS.

xi

Page

VI. Lead	-	-	-	-	-	315
Compounds of lead with oxygen	-	-	-	-	-	316
Compounds of the protoxide of lead with acetic acid	-	-	-	-	-	318
Carbonate of lead	-	-	-	-	-	318
Compounds of lead with the halogen class	-	-	-	-	-	319
Compounds of lead with sulphur and selenium	-	-	-	-	-	319
Sect. VII. Tin	-	-	-	-	-	320
Compounds of tin with oxygen	-	-	-	-	-	320
Compounds of tin with the halogen class	-	-	-	-	-	321
Compounds of tin with sulphur and selenium	-	-	-	-	-	321
VIII. Bismuth	-	-	-	-	-	322
Compounds of bismuth with oxygen	-	-	-	-	-	323
Compounds of bismuth with the halogen class	-	-	-	-	-	323
Compounds of bismuth with sulphur and selenium	-	-	-	-	-	324
IX. Iron	-	-	-	-	-	324
Compounds of iron with carbon, boron, silicon, and phosphorus	-	-	-	-	-	325
Compounds of iron with oxygen	-	-	-	-	-	326
Reaction of iron with acids	-	-	-	-	-	328
Compounds of iron with the halogen class	-	-	-	-	-	329
Compounds of iron with sulphur and selenium	-	-	-	-	-	330
X. Zinc	-	-	-	-	-	331
Compounds of zinc with oxygen	-	-	-	-	-	331
Compounds of zinc with the halogen class	-	-	-	-	-	333
Compounds of zinc with sulphur and selenium	-	-	-	-	-	333
XI. Arsenic	-	-	-	-	-	334
Compounds of arsenic with oxygen	-	-	-	-	-	335
Compounds of arsenic with the halogen class	-	-	-	-	-	338
Compounds of arsenic with sulphur and selenium	-	-	-	-	-	338
Compounds of arsenic with phosphorus and hydrogen	-	-	-	-	-	339
Means of detecting arsenic in cases where poisoning is suspected by it	-	-	-	-	-	340
XII. Antimony	-	-	-	-	-	344
Sesquioxide of antimony	-	-	-	-	-	345
Compounds of antimony with oxygen of minor importance	-	-	-	-	-	346
Compounds of antimony with the halogen class	-	-	-	-	-	347
Compounds of antimony with sulphur and selenium	-	-	-	-	-	347
XIII. Metals proper of minor importance	-	-	-	-	-	350
Palladium	-	-	-	-	-	350
Rhodium	-	-	-	-	-	350
Iridium	-	-	-	-	-	351
Osmium	-	-	-	-	-	351
Nickel	-	-	-	-	-	351
Cadmium	-	-	-	-	-	352
Chromium	-	-	-	-	-	352
Cobalt	-	-	-	-	-	354
Columbium	-	-	-	-	-	354
Manganese	-	-	-	-	-	354
Molybdenum	-	-	-	-	-	354
Titanium	-	-	-	-	-	355
Tungsten	-	-	-	-	-	355
Uranium	-	-	-	-	-	355
Cerium	-	-	-	-	-	355
Vanadium	-	-	-	-	-	355
Sect. I. Oxyacids	-	-	-	-	-	359
Chlorates and hypochlorites	-	-	-	-	-	359
Oxychlorates	-	-	-	-	-	364
Nitrates	-	-	-	-	-	364
Nitrites and hyponitrites	-	-	-	-	-	365

Sulphates	-	-	-	-	-
Hyposulphates, sulphites, and hyposulphites	-	-	-	-	-
Seleniates	-	-	-	-	-
Phosphates	-	-	-	-	-
Phosphites	-	-	-	-	-
Carbonates	-	-	-	-	-
Borates	-	-	-	-	-
Silicates	-	-	-	-	-
Cyanates and fulminates	-	-	-	-	-
Double oxysalts	-	-	-	-	-
SECT. II. Sulphosalts	-	-	-	-	-
III. Selenisalts and tellurisalts	-	-	-	-	-
IV. Chlorosalts, bromosalts, iodosalts, and fluosalts	-	-	-	-	-
V. Cyanosalts	-	-	-	-	-

## DEFINITIONS OF CHEMISTRY.

It is natural that a person whose attention may be directed to chemistry should inquire of what does it treat, or how is it to be defined or distinguished from other sciences?

Agreeably to the definition given in the second page of the Compendium of chemistry treats of those phenomena and operations of nature which result from reaction between particles of inorganic matter.

I subjoin several other definitions from some of the most celebrated modern writers on chemistry.

*Thomson* defines chemistry to be "the science which treats of the events or changes in natural bodies, which are not accompanied by sensible motions."

*Henry* conceives that "it may be defined, the science which investigates the composition of material substances, and the permanent changes of constitution, which their mutual actions produce."

According to *Murray*, "it is the science which investigates the combinations of matter, and the laws of those general forces, by which combinations are established and subverted."

*Brande* alleges "that it is the object of chemistry to investigate changes in the constitution of matter, whether effected by heat, mixture, or other means."

According to *Ure*, "chemistry may be defined that science, the object of which is to discover and explain the changes of composition that take place among the integrant and constituent parts of different bodies."

The definition given by *Berzelius* is as follows:—"Chemistry is that science which makes known the composition of bodies, and the manner in which they comport with each other."

COMPENDIUM  
OF  
CHEMICAL INSTRUCTION,

&c.

---

INTRODUCTION.

1. The phenomena and operations of the material world appear to be dependent on certain properties in the particles or masses of matter which enable them to exercise a reciprocal influence. Without this reciprocal action, which I would prefer to call reaction,\* every particle or mass would be as if no other existed, and could itself have no efficient existence.

2. The reciprocal action or reaction, thus inferred to exist, may be distinguished as taking place between masses, between a mass and particles, and between particles only.

3. *Reaction between masses*† is sublimely exemplified in the solar system, by that attraction between the sun and planets, by which they are made to revolve in their orbits.

4. *Reaction between a mass and particles* is exemplified by the reflection, refraction, and polarization of light.

5. *Reaction between particles* is exemplified by a fire, or the explosion of gunpowder.

*Definition of Natural Philosophy, Chemistry, and Physiology.*

6. *Natural Philosophy*, in its most extensive sense, treats of physical reaction generally. In its more limited and

\* In Mechanics, action is said to produce reaction; but in the case of an innate property, which mutually causes different portions of matter to be self attractive, or repellant, it is impossible to distinguish the agent from the reagent. From our disengagement with any bodies so situated, they may be said mutually to react, or to exercise reaction.

† By the word mass, I mean a congeries of particles capable of producing some effect collectively, to which severally they would be incompetent.

usual acceptation, it treats of those phenomena and operations of nature, which arise from reaction between masses, or between a mass and particles.

7. *Chemistry* treats of the phenomena and operations of nature, which arise from the reaction between the particles of inorganic matter.

8. *Physiology* treats of the phenomena and operations, which arise from the reaction of the masses or atoms of organic or living bodies.

#### OF CHEMICAL REACTION.

9. Reaction between particles, or chemical reaction, is distinguished into repulsive reaction or repulsion, and attractive reaction or attraction.

#### OF REPULSIVE REACTION OR REPULSION.

*A Priori Proofs that there must be a Matter in which Repulsion exists as an Inherent Property.*

10. Matter may be defined to be that which has properties. We know nothing of matter directly. It is only with its properties that we have a direct acquaintance. It is from our perception of matter, through the powers or properties by which it affects our senses, that we believe in its existence.

11. The existence of repulsion and attraction is as evident as that of the matter which, in obedience to their successive predominancy, may be seen either to cohere, in solids, with great tenacity, or to fly apart with explosive violence in the state of a vapour. The existence of repulsion and attraction being proved, it must be admitted that they are properties of matter; since the existence of a property, independently of matter, is inconceivable. But being of a nature to counteract each other, the repellent and attractive powers cannot coexist in particles of the same kind, and consequently must belong to particles of different kinds. There must, therefore, be a matter endowed with repulsion, distinct from that which is endowed with attraction.

12. I conceive that the phenomena of chemistry demonstrate that there are at least the three following properties, which, from their obvious incompatibility, cannot belong to the same elementary particles.

13. 1st. An innate property of reciprocal attraction.

14. 2d. An innate property of counteracting attraction directly, by imparting reciprocal repulsion.

15. 3d. An innate property of imparting an attraction, variable in its force, and limited and contingent in its duration.

16. I presume that there must be at least three different kinds of matter, to each of which, one of the properties thus specified innately appertains.

17. The permanent and unvarying attractive power is exemplified by gravitation, and, as modified by circumstances, by tenacity, or cohesion.

18. It resides, undoubtedly, in every kind of matter endowed with weight, and consequently in all that is considered as material by the mass of mankind.

19. It must likewise act between each of those imponderable principles which I am about to mention, and all other matter, whether ponderable or imponderable.

20. The power of imparting reciprocal repulsion to ponderable matter is supposed by chemists generally to belong to certain imponderable material reciprocally repulsive particles, constituting the cause of heat, called caloric.

21. The power of indirectly counteracting attraction, and substituting for it a contingent and variable attraction, appears to belong to electricity. Light also appears to exercise a modifying influence.

22. Thus we have reason to infer the existence of at least three imponderable substances—electricity, caloric, and light—each consisting of particles reciprocally repulsive, yet attractive of other matter, and probably more or less attractive of each other.

#### OF CALORIC.

#### *Experimental Proofs of the Existence of a material Cause of Calorific Repulsion.*

23. It has been ascertained that ice melts and water freezes at the temperature of 32° of Fahrenheit's thermometer. If at this temperature, which is called the freezing point, ice in a divided state, as in that of snow for instance, be mingled with an equal weight of water at 172°,

the ice will be melted, and the resulting temperature will be  $32^{\circ}$ ; but if equal weights of water be mingled at those temperatures, the mixture will have the mean heat of  $102^{\circ}$ .

24. It follows that a portion of heat becomes latent in the aqueous particles during the liquefaction of the ice, sufficient to raise an equal weight of water one hundred and forty degrees. In this case the ice is supposed to combine with material caloric particles, innately endowed with a power of reciprocal repulsion, and likewise with that of combining with ponderable matter. Hence water is considered as a combination of ponderable particles, endowed with a reciprocally attractive power, and imponderable particles endowed with a reciprocally repellent power; so that, in obedience to the power last mentioned, the compound atoms, instead of cohering as in the solid state, move freely among each other, forming consequently a liquid.

25. In all cases of liquefaction or fusion which have been examined, analogous results have been observed; whence it is generally believed that whenever a solid is converted into a liquid, its particles unite with a portion of the material cause of heat, which becomes latent, as in the case of ice in melting. The evidence is equally strong in favour of the inference that in passing from the liquid to the aëriform state, ponderable matter combines with, and renders latent even a larger quantity of heat in proportion to its weight, than in cases of liquefaction.

26. When, by means of a thermometer, we observe the rise of temperature in water exposed to a regular heat, as when placed in a cup upon a stove, we find that nearly equal increments of heat are acquired in equal times, until the boiling point is attained. Subsequently, the cup being open so as to allow the steam to escape freely, no further rise of temperature will be found to ensue; but in lieu of it, steam will be evolved more or less copiously, in proportion to the activity of the fire. Since from the time the water boils it ceases to grow hotter, it may be fairly presumed that the steam generated during the ebullition, although of a temperature no higher than  $212^{\circ}$ , contains, in a latent state, the caloric which meanwhile enters the liquid. This presumption is fully justified by the fact, that if any given weight of steam be received in a quantity of

cool water ten times heavier, it will cause in it a rise of temperature of nearly one hundred degrees.

7. The heat which would raise ten parts of water to 100 degrees, would, if concentrated into one of those parts, raise it to 1000 degrees nearly, which is about equal to a red heat. It follows, therefore, that as much heat is absorbed in producing steam, as would render the water of which it consists red-hot, if prevented from assuming the striform state.

28. These facts and deductions induce chemists generally to believe that the cause of calorific repulsions is material; that it consists of a fluid, of which the particles are self-repellent, while they attract other matter; that by the union of this fluid with other matter, a repulsive property is imparted, which counteracts cohesion, so as to cause, successively, expansion, fusion, and the aëriform state; and further, that it is by the afflux of the calorific matter that the sensation of heat is produced, while that of cold results from its efflux.

#### *Acceptation of the term Caloric.*

29. If we place a small heap of fulminating mercury upon the face of a hammer, and strike it duly with another hammer, an explosion will ensue so violent as to cause a visible indentation in the steel surface. This explosion, agreeably to the premises, can only be explained by supposing the evolution of a great quantity of the material cause of heat. Were an equal quantity of red-hot sand to be suddenly quenched with water, the effect would be comparatively feeble. We may, therefore, infer that the fulminating powder, though cold, contains more of the cause of heat than a like quantity of red-hot sand. Hence it would follow from using the word heat in the sense both of cause and effect, that there is more heat in a cold body than in a hot one, which in language is a contradiction. On this account it was considered proper by the chemists of the Lavoisierian school, to use a new word, *caloric*, to designate the material cause of calorific repulsion.

#### *Experimental Illustration.*

30. A portion of fulminating mercury exploded between two hammers.

## ORDER PURSUED IN TREATING OF CALORIC.

**EXPANSION.**—MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.—CAPACITIES FOR HEAT, OR SPECIFIC HEAT.—SLOW COMMUNICATION OF HEAT, COMPRISING THE CONDUCTING PROCESS AND CIRCULATION.—QUICK COMMUNICATION OF HEAT, OR RADIATION.—MEANS OF PRODUCING HEAT, OR RENDERING CALORIC SENSIBLE.—MEANS OF PRODUCING COLD, OR RENDERING CALORIC LATENT.—STATES IN WHICH CALORIC EXISTS IN NATURE.

## EXPANSION.

OF THE EXPANSION OF SOLIDS, LIQUIDS, AND ELASTIC FLUIDS, AND ON THE OPPONENT AGENCY OF ATMOSPHERIC AND OTHER PRESSURE.

*Expansion of Solids.*

31. A ring and plug, which when cold fit each other, cease to do so when either is heated; and a tire when *red-hot* is made to embrace a wheel otherwise too large for it.

*Pyrometer, in which the Extension, in length, of a Metallic Bar is rendered sensible by a Combination of Levers.*

32. The influence of temperature on the length of a metallic wire may be rendered evident by means of the instrument, of which fig. 1, in the opposite engraving is a representation.

33. WW, represents a wire, beneath which is a spirit lamp consisting of a long, narrow, triangular vessel of sheet copper, open along the upper angle, so as to receive and support a strip of thick cotton cloth, or a succession of wicks. By the action of the screw at S the wire is tightened, and by its influence on the levers, the index I is raised. The spirit lamp is then lighted and the wire enveloped with flame. It is of course heated and expanded, and, allowing more liberty to the levers, the index upheld by them falls.

34. By the action of the screw the wire may be again tightened, and, the application of the lamp being continued, will again, by a further expansion, cause the depression of the index; so that the experiment may be repeated several times in succession.

35. Since this figure was drawn, I have substituted for the alcohol lamp the more manageable flame of hydrogen gas, emitted from a row of apertures in a pipe supplied by an apparatus for the generation of that gas. See fig. 2.

36. If, while the index is depressed by the expansion, ice or cold water be applied to the wire, a contraction immediately follows so as to raise the index to its original position.

37. *Metals are the most expansible solids, but some are more expansible than others.*

38. The following table, abstracted by Turner from that furnished by Lavoisier, will show the increase of bulk obtained by glass and various metals in rising in temperature from 32° to 212°.



*Instrument  
demonstrating the Power of Caloric in expanding a Metallic Rod.*

FIG. 1.

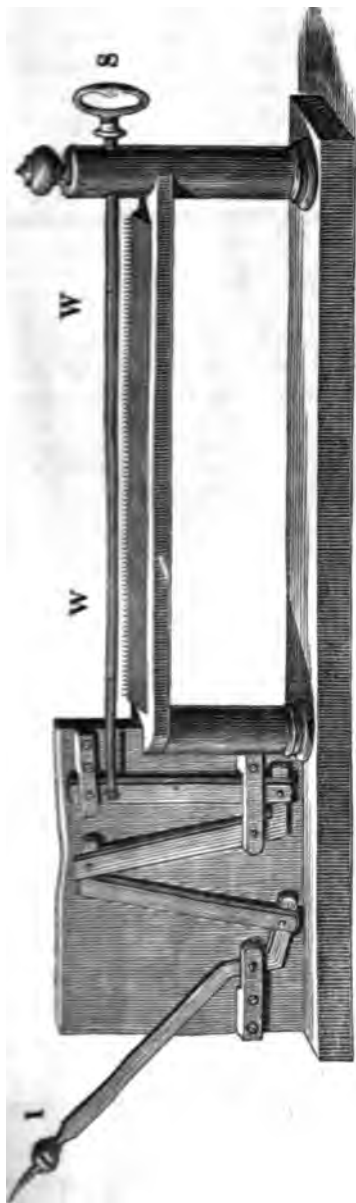
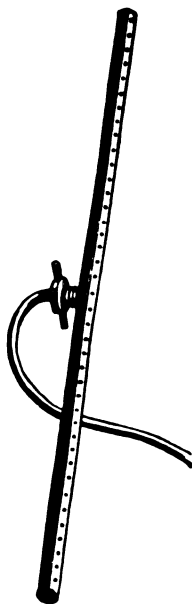


FIG. 2.





*Uses of Substances.**Elongation when heated  
from 32° to 212°.*

tube without lead, mean of three specimens	- -	1-1115 of its length.
thin flint glass,	- -	1-1248
iron,	- -	1-581
tin, mean of two specimens,	- -	1-532
iron, forged,	- -	1-819
wire,	- -	1-812
tempered steel,	- -	1-927
annealed steel,	- -	1-807
iron,	- -	1-351
of India,	- -	1-516
of Falmouth,	- -	1-462
iron,	- -	1-524
tin, mean of three specimens,	- -	1-602
iron, determined by Borda,	- -	1-1167

8. Pyrometers have been made of platinum, in one of which, invented *Daniel*, changes in the length of a cylinder of this metal, arising from *temperature*, are made sensible by the motion of a lever associated with it, which acts as an index. In the other, a bulb is formed of platinum, the degree of heat is inferred from the quantity of air expelled.

9. The use of this air pyrometer is burdened by the necessity of measurement and calculation to ascertain the result. This might be very much *improved* by the use of a sliding rod and air-gauge. The retraction of *rod* might be made to compensate the expulsion of air, while divisions made on it would indicate the quantity.

### *Experimental Illustration of the different Expansibility of Metals.*

11. That the expansibility of one metal may exceed that of another, may be rendered apparent by soldering together, face to face, two thin strips, one iron the other brass. On exposure to heat, the compound strip, thus constituted, assumes the shape of an arch. The brass, which is the more expansible metal, forms the *outer* and of *course* larger curve.

### *Supposed Exception to the Law that Solids expand by Heat in the case of Clay, which contracts in the Fire.*

12. The phenomena do not justify us in considering the retraction of clay from heat as an exception to the general law. In the first instance clay shrinks by losing water, of which the last portions are difficult to expel. In the next place a chemical union takes place between the principal ingredients, silica and alumina, which is rendered more complete in proportion to the duration and intensity of the fire. It may be presumed that the vitreous com-

pound, which would result from a complete fusion and combination of the constituents, would be as expansible as other vitreous substances.

*Experimental Illustration.*

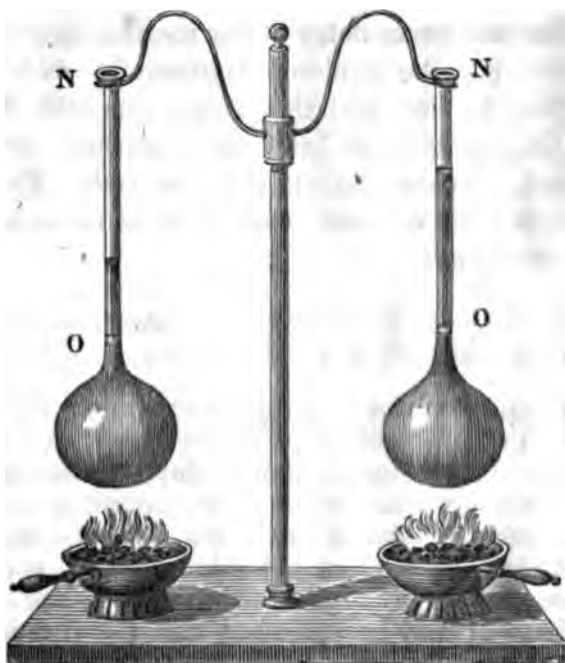
43. The contraction produced by heat in cylinders of clay shown by means of the ingenious but inaccurate pyrometer of Wedgwood.

*Expansion of Liquids or non-elastic Fluids.*

44. The word fluid applies to every mass that will flow and distribute itself equally in obedience to its own weight and self-repulsion.

45. Ponderable fluids are either elastic or non-elastic. Latterly the term *liquid* has been employed to designate those fluids which are, like water, alcohol, and oil, devoid of elasticity, a property which, in due time, I shall define and illustrate.

*Liquids are expanded when their Temperature is raised, as some Liquids are more expansible than others.*



46. Let two glass vessels be provided with bulbs and necks of the same shape and dimensions as represented in the preceding figure. Let one of them, that on the left for instance, be supplied with as much alcohol as will occupy it to the level designated by the letters O O. Let the vessel on the right be occupied with water to the same level, the height of the liquid in each being made to correspond with a little fillet of white paper secured about the neck. Under each vessel, place equal quantities of charcoal, burning with a similar degree of intensity; or preferably, surround the bulbs simultaneously with hot water in an oblong vessel of suitable dimensions. The liquids in each vessel will be expanded so as to rise into the necks; but the alcohol will rise to a greater height than the water.

47. The dilatation of the following liquids, by a change of temperature from  $32^{\circ}$  to  $212^{\circ}$ , is as follows—alcohol 1-9, nitric acid 1-9, fixed oils 1-12, sulphuric ether 1-14, oil of turpentine 1-14, sulphuric or muriatic acid 1-17, brine 1-20, water 1-23 nearly, mercury about 1-55.

48. The rate of expansion for liquids increases with the temperature; as if their particles, by becoming more remote, lost some of their ability to counteract the repulsive influence of caloric.

49. The number associated with each of the substances in the following list, shows its melting point as estimated by Fahrenheit's scale. One degree of Daniell's pyrometer, ( $39^{\circ}$ ) by which the temperatures above  $600^{\circ}$  were measured, is calculated to be equal to seven of Fahrenheit.

50. Cast iron  $3479^{\circ}$ , gold  $2590^{\circ}$ , silver  $2233^{\circ}$ , brass  $1869^{\circ}$ , antimony  $810^{\circ}$ , zinc  $648^{\circ}$ , lead  $606^{\circ}$ , bismuth  $497^{\circ}$ , tin  $442^{\circ}$ , sulphur  $218^{\circ}$ , beeswax  $142^{\circ}$ , spermaceti  $112^{\circ}$ , phosphorus  $108^{\circ}$ , tallow  $92^{\circ}$ , olive oil  $36^{\circ}$ , milk  $30^{\circ}$ , blood  $25^{\circ}$ , sea water  $274^{\circ}$ , oil of turpentine  $14^{\circ}$ , mercury— $39^{\circ}$ , nitric acid— $151^{\circ}$ , sulphuric ether— $46^{\circ}$ .

### *Exception to the Law that Liquids expand by Heat.*

51. The bulk of water diminishes with the temperature, until it reaches  $39^{\circ}$  nearly. Below this point, it expands and grows colder, and in freezing increases in bulk one-fourth. This wonderful exception to the law that liquids expand by heat, appears to be a special provision of the Deity for the preservation of aquatic animals; for were

water to increase in density as it approaches the point of congelation, the upper stratum would continue to sink as refrigerated in bodies of water below  $39^{\circ}$ , as well as in others. Hence a whole river, lake, or sea might, in high latitudes, be rendered too cold for animal life; and finally be so far converted into ice, as not to thaw during the ensuing summer. Subsequent winters co-operating, the whole might be consolidated so as never to thaw. But in consequence of the peculiarity in question, the coldest stratum, in a body of water below  $39^{\circ}$ , remains at top until, if the cold be adequate, congelation ensues. The buoyant sheet of ice, which results in this case, forms effectively a species of winter clothing to the water beneath it; and, by augmenting with the frost, opposes an increasing obstacle to the escape of caloric from the water which it covers.

### *Expansion of Aëriform Fluids.*

52. Aëriform fluids are much more expansible than liquids. In order, however, to appreciate the changes of bulk which they may be observed to sustain, it is necessary to understand the influence which the pressure of the atmosphere has upon their density, independently of temperature. The simple influence of heat, in expanding them may be illustrated by holding a hot iron over the thermometer of Sanctorio, represented in the following figure.

### *Thermometers.*

53. The invention of the thermometer is ascribed to Sanctorio. The principle of that form of the instrument which he contrived may be understood from the following article.

*Expansion of Air illustrated by the Air Thermometer of Sanctorio on a large Scale.*



54. The bulb of a matraass is supported by a ring and an upright wire with its neck downwards, so as to have its orifice beneath the surface of the water in a small glass jar. A heated iron being held over the matraass, the contained air is so much increased in bulk, that, the vessel being inadequate to hold it, a partial escape from the orifice through the water ensues. On the removal of the hot iron, the residual air regains its previous temperature, and the portion expelled by the expansion is replaced by the water.

55. If in this case the quantity of air expelled be so regulated, that when the remaining portion returns to its previous temperature, the liquid rises about half way up the stem, or neck, the apparatus will constitute an air thermometer. For whenever the temperature of the external air changes, the air in the bulb of the matraass

will, by acquiring the same temperature, sustain a corresponding increase or diminution of bulk, and consequently, in a proportionate degree, influence the height of the liquid in the neck. As elastic fluids are dilated or contracted, in proportion to the temperature, and are also much more expandable than liquids, this thermometer would be very accurate, as well as independent in sensibility, were it not influenced by atmospheric pressure as well as temperature. On this account, however, it was never of much utility. Subsequently, liquids were resorted to, and the instrument assumed a form now generally employed, the principle of which is explained. (45.)

56. In the following pages I shall give engravings and descriptions of a form of the thermometer used in the laboratory, of the self-registering thermometer, of the differential thermometer, and of an apparatus which illustrates the difference between it and Sanctorio's thermometer.

57. Agreeably to the example of my predecessor and preceptor Dr. W. Brouncker. I have been accustomed to exhibit to my class the blowing and filling of a thermometer. Of this process an account is subjoined.

58. The tubes used in constructing thermometers are made at almost all the glass works, having usually a capillary perforation. They are made by rapidly drawing a hollow glass globe while red-hot, by which means it is changed into a long, slender string of glass, in the axis of which a perforation exists, in consequence of the cavity of the globe. When a thermometer tube is softened by exposure to a flame, excited by a blow-pipe, a bulb may be blown upon it. While the bulb is still hot, the other end of the tube is immersed in mercury, or in spirit, according to the purposes for which the instrument is intended. As the bulb cools, the air within contracts, and thus allows the liquid to enter, in obedience to the pressure of the atmosphere. The bulb thus becomes partially supplied with the liquid, which is sufficient in order to expel all the air from the cavity of the bulb and perforation.

The orifice being again depressed into the liquid, when the whole becomes cold the liquid will fill the cavity of the bulb. This result will be hereafter fully explained and illustrated. The open end of the tube being now heated, is drawn out into a filament with a capillary perforation. The bulb being raised to a temperature above the intended range of the thermometer, so as to expel all the superabundant liquid, the point is fused so as to seal the orifice hermetically, or in other words so as to be perfectly air-tight. In the next place, the bulb is to be exposed to freezing water, and the point to which the liquid reaches in the capillary perforation marked. In like manner the boiling point is determined, by subjecting the bulb to boiling water. The distance between the freezing and boiling points, thus ascertained, may be divided according to the desired graduation.

59. The scale of Reaumur requires 80 divisions, that of Celsius 100, Fahrenheit's 180. The graduation of Celsius is the most rational; that of Fahrenheit the least so, although universally used in Great Britain and the United States. The degrees of these scales are to each other obviously, as 80, 100, and 180; or as 4, 5, and 9. Hence it is easy to convert the one into the other by the rule of three.

60. It should, however, be observed that the scales of Celsius and Reaumur commence at the freezing of water, all above that being plus, all below it minus; while the scale of Fahrenheit commences at thirty-two degrees below freezing. Hence in order to associate correctly any temperature noted by his thermometer with theirs, we must ascertain the number of degrees which the mercury is above or below freezing, and convert this number into one equivalent to it by their graduation; and conversely, after changing any number of degrees of theirs into his, we must consider the result as indicating the number of degrees above or below 32 on his scale.

61. The process above described for the construction of a thermometer, is equally applicable whether the bulb be filled with alcohol or mercury. Each of these liquids has peculiar advantages. Mercury expands most equably. Equal divisions on the scale of the mercurial thermometer will more nearly indicate equal increments or decrements of temperature. Mercury also affords a more extensive range; as it does not boil below  $656^{\circ}$ , nor freeze above  $-39^{\circ}$ , of Fahrenheit's thermometric scale.

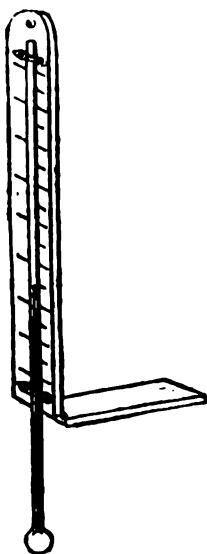
62. Alcohol, being more expansible than mercury, is more competent to detect slight changes. It boils at  $176^{\circ}$  of Fahrenheit, and for its congelation is alleged to require  $-90^{\circ}$  of the same scale. As this temperature is below any ever observed in nature, and can only be attained by an extremely difficult process, latterly discovered by Bussier, it can hardly ever happen that an alcoholic thermometer will not be found competent to measure any degree of cold which chemists have a motive for determining. Besides those above mentioned, a thermometric scale has been used in Russia, which bears the name of its author, Delisle. In this, zero is at the boiling point of water, and five of his graduations are equal to six of Fahrenheit's.

#### *Laboratory Thermometer.*

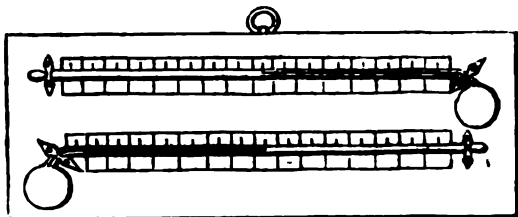
63. The thermometers used in laboratories, are usually constructed so as to have a portion of the wood or metal, which defends them from injury and receives the graduation, to move upon a hinge, as represented in the adjoining figure.

64. This enables the operator to plunge the bulb into fluids, without introducing the wood or metal, which would often be detrimental either to the process or to the instrument, if not to both.

65. The scale is kept straight by a little bolt on the back of it, when the thermometer is not in use.



#### *Self-registering Thermometer.*



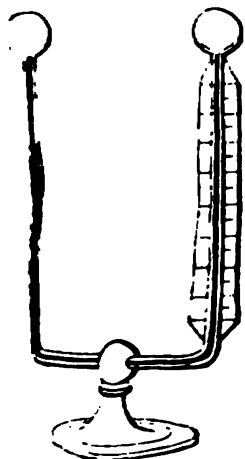


66. The figure represents a self-registering thermometer. It comprises necessarily a *mercurial* and a *spirit thermometer*, which differ from those ordinarily used, in having the stems horizontal and their bores round; also large enough to admit a cylinder of enamel in the bore of the spirit thermometer, and a cylinder of steel in the bore of the mercurial thermometer. Both the cylinder of enamel and that of steel must be nearly of the same diameter with the perforations in which they are respectively situated, as is consistent with their moving freely in obedience to gravity, or any gentle impulse.

67. In order to prepare the instrument for use, it must be held in such a situation, that the enamel may subside as near to the end of the alcoholic column as possible, yet still remaining within this liquid. The steel must be in contact with the mercury, but not at all immersed in it.

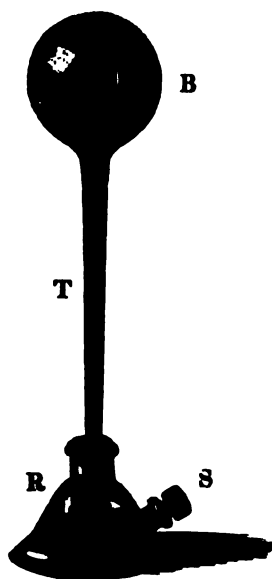
68. On this account the bulbs of the thermometers are placed at opposite ends of the plate upon which they are secured; so that when this plate is made to stand up on one end, in such manner as to have the bulb of the mercurial thermometer lowermost, that of the spirit thermometer will be uppermost. Under these circumstances, impelled by gravity, the steel cylinder will subside upon the surface of the mercurial column, while the cylinder of enamel will sink within the little column of spirit, which raises it, till it reaches the surface of that column. The instrument being, after the object is attained, suspended in a horizontal position, as represented in the figure, if in consequence of its expansion by heat, the mercury advance into the tube, the steel moves before it; but should the mercury retire during the absence of the observer, the steel does not retire with it. Hence, the maximum of temperature, as the interim, is discovered by noting the graduation opposite the end of the cylinder nearest the mercury. The minimum of temperature is registered by the enamel, which retreats with the alcohol when it contracts, but, when it expands, does not advance with it. The enamel must retire with the alcohol, since it lies at its margin, and cannot remain unmoved in the absence of any force competent to extricate it from a liquid, towards which it exercises some attraction. But when an opposite movement takes place, which does not render its extrication from the liquid necessary to its being stationary, the enamel does not accompany the alcohol. Hence the minimum of temperature, which may have intervened during the absence of the observer, is discovered by ascertaining the degree opposite the end of the enamel nearest to the end of the column of alcohol.

#### *Leslie's Differential Thermometer.*



69. This instrument consists of a glass tube nearly in the form of the letter U, with a bulb at each termination. In the bore of the tube there is some liquid, as, for instance, coloured sulphuric acid, alcohol, or ether. When such an instrument is exposed to any general alteration of temperature in the surrounding medium, as in the case of a change of weather, the air in both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest change of temperature exclusively affects one of the bulbs. Any small bodies situated at different places in the same apartment warmed by a fire, will show a diversity of temperature, when severally applied to the different bulbs.

*Difference between an Air Thermometer and a Differential Thermometer, illustrated upon a large Scale.*

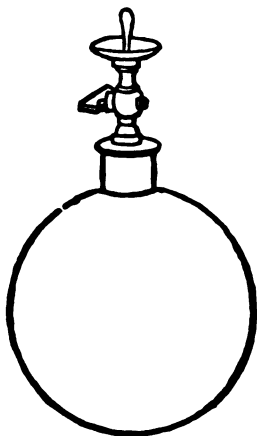


70. The adjoining figure represents an instrument, which acts as a thermometer, when the stopper is removed from the tubulure in the cal recipient, R; because in this case whenever the density of the sphere varies either from change of temperature, or barometrical pressure hereafter to be explained, the alteration will be indicated by an increase or diminution of the liquid in the bulb, and of course by a corresponding movement of the liquid in the tube T. But when the stopper is in its place the air cannot, within either cavity of the instrument, be affected by change in atmospheric pressure: no changes of temperature which are equally on both cavities, produce movement in the liquid which indicates them. Hence, under the circumstances, the instrument is content to act only as a differential thermometer.

### MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.

*Digression to demonstrate the Nature and Extent of Atmospheric Pressure.*

*Experimental Proof that Air has Weight.*



71. The air being allowed to replenish the exhausted globe, while suspended from a beam and accurately counterpoised, causes it to preponderate.

72. By a temporary communication with an air pump, by means of a screw with which it is furnished, a glass globe is exhausted. It is then suspended to one arm of a scale and accurately counterpoised. Being thus compared, if by opening the cock the air is allowed to re-enter the globe, it will preponderate; and if a quantity of water, adequate to restore the equilibrium, be introduced into a small vessel, duly equipoised by a counterweight applied to the other arm of the scale, the inequality in bulk of equal weights of air and water will be satisfactorily exhibited.

### *Definition of Elasticity.*

1. The power which bodies have to resume their shape, position, or on the cessation of constraint, is called *elasticity*. The degree in any body possesses this power is not to be estimated by the force, or the perfection of its recoil. A coach spring is far more powerful, but not more elastic, than a watch spring.

. Elasticity is erroneously spoken of as a varying property in the air, but in common with æriform fluids in general, appears to be always *equally elastic*.

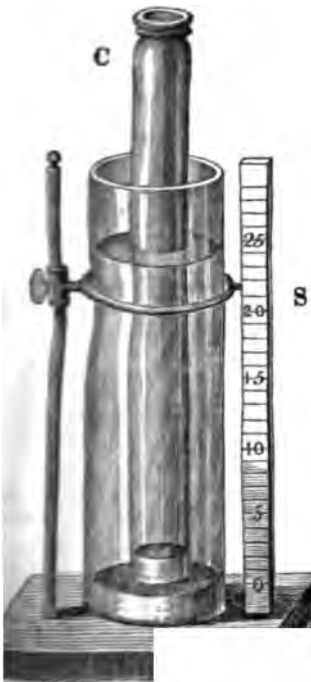
. As a property distinguishing æriform fluids from liquids, elasticity conveys the idea of a power in a given weight of a fluid to expand or to contract with the space in which it may be confined, producing at the same time a pressure on the internal surface of the cavity, or any object within *equally* as the space.

*Existence and Extent of the Pressure of the Atmosphere experimentally demonstrated.*

#### PRELIMINARY PROPOSITION.

*For the pressure of any fluid on any area assumed within it, the pressure of a column of any other fluid may be substituted, making it as much higher as lighter, as lower as heavier; or in other words, the heights are inversely as the gravities.*

*Experimental Illustration in the case of Mercury and Water.*



77. If into a tall glass jar, such as is represented in the adjoining figure, a glass cylinder, C, (like a large glass tube open at both ends) were introduced—on filling the jar with water, this liquid would of course rise in the cylinder to the same height as in the jar; but, if, as in the figure, before introducing the water, the bottom of the jar be covered with a stratum of mercury, two inches deep, so as to be sufficiently above the open end of the cylinder, it must be evident that the water will be prevented from entering the cylinder by the interposition of a heavier liquid. But as the pressure of the water on the mercury outside of the cylinder is unbalanced by any pressure from water within the cylinder, the mercury within will rise, until, by its weight, the external pressure of the water is compensated. When this is effected, it will be seen, on comparing, by means of the scale, S, the height of the two liquids, that for every inch of elevation acquired by the mercury, the water has risen more than a foot; since the weight of mercury is to that of water, as 13.6 to 1.

78. It may be demonstrated that the pressure of the column of mercury is equivalent to that of a column of water having the same base, and an altitude equal to that of the water in the jar, by filling the cylinder with water. It then be seen, that, when the water inside of the cylinder is on a level with water on the outside, the mercury within the cylinder is also on a level with mercury without.

79. It is, therefore, obvious, that the elevation of the column of mercury, with tube, is produced by the weight or pressure of the water without, and measure extent of that pressure on the lower orifice of the tube.

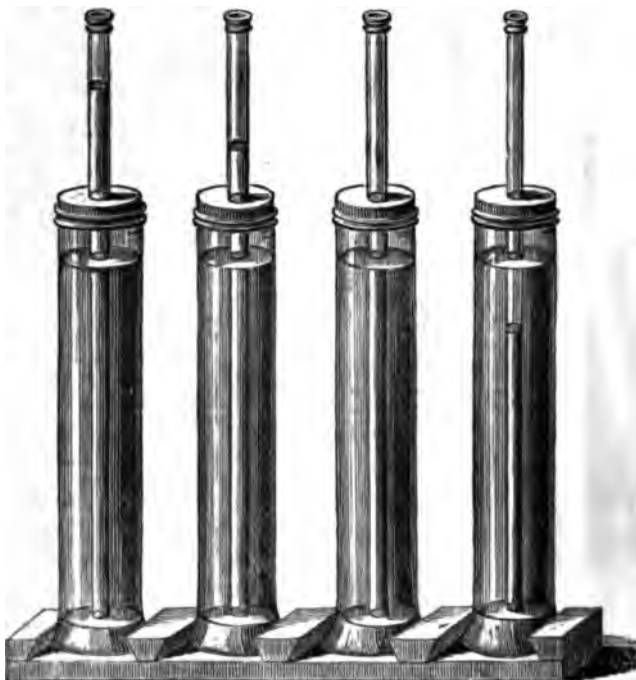
*The Illustration extended to the case of Liquids lighter than Mercury.*

80. Let there be four jars, each about four inches in diameter, and more than inches in height, severally occupied by mercury to the depth of about two inches. In the axis of each jar, let a tube be placed, of about one inch and a half in diameter, and about one-fourth taller than the jar, with both ends open, and the orifice under the surface of the mercury. On pouring water into the jars, the mercury rises in the tubes, as the water rises in the jars; but the mercury rises as less than the water as it is heavier.

81. The mercurial columns in this case, as in the preceding experiment, owe existence to the pressure of the surrounding water, and by their height measure the extent of that pressure on the areas of their bases respectively. They may be considered as substituted severally for the aqueous columns, which would have existed had not the mercury been interposed. Accordingly, water poured into one of the tubes, the mercury in that tube subsides to a level with mercury without, when the water poured into the tube reaches the level of water without.

82. The three remaining columns of mercury may be considered as substitutes in water, for columns of water, and being as much lower as heavier are found, quite to preserve the equilibrium.

83. It remains to be proved that other fluids, heavier or lighter than water, may like manner be substituted for the columns of mercury, and of course for the water which the mercury is the representative.



54. In the three tubes, in which, by the addition of water to the jars, columns of mercury are sustained, pour severally, ether, alcohol, (differently coloured, so that they may be distinguished) and a solution of sulphate of copper, until the mercurial column within the tubes, are reduced to a level with the mercury without. It will be found that the column formed by the cupreous solution is much lower than the surface of the water on the outside of the tube; that the opposite is true of the column of alcohol; and that the ether, still more than the alcohol, exceeds the surrounding water in elevation.

55. While it is thus proved that columns of mercury, ether, alcohol, and of a dense liquid may, in water, be substituted for columns of this liquid; it is also apparent that they must be as much higher as lighter, as much lower as heavier; or in other words, their heights must be inversely as their gravities.

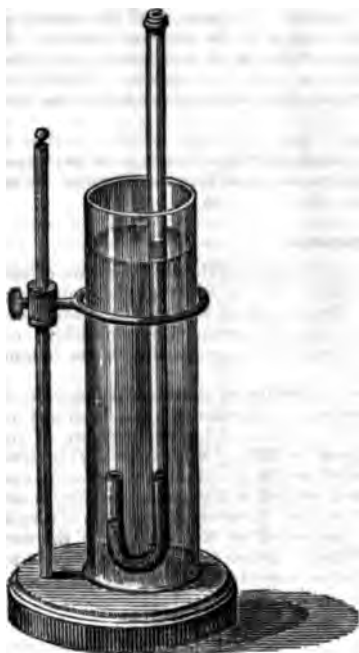
#### *Torricellian Experiment.*

56. Pursuant to the law which has been above illustrated, that the pressure of one fluid may be substituted for that of another, provided any difference of weight be compensated by a corresponding difference in height; if, in lieu of water, the mercury were pressed by air on the outside of the tubes, unbalanced by air within, columns of the metal would be elevated, which would be in proportion to the height of weight of the air thus acting upon it.

57. In order to show that the air exercises a pressure on the mercury outside of the tubes, analogous to that exercised by water in the experiments just described, it only remains that this external pressure be unbalanced by the pressure of air within the tube. This desideratum is obtained by filling, with mercury, a tube about three feet in length, open at one end and closed at the other, and covering the open end with the hand, until it be inverted and merged in a vessel containing some of the same metal, without allowing any air to enter. A mercurial column of about thirty inches in height will remain in the tube, supported by the pressure of the surrounding air, and an index of its weight. This is a case obviously analogous to that of the mercurial columns, supported by the pressure of water in the experimental illustration above given.



58. The tube may be *supposed* to occupy either of the three positions, represented in the drawing. The mercury, in each position, preserves the same degree of elevation, its surface being always in the same horizontal plane, or level, whether upright or inclined. Or we may suppose three tubes, filled with mercury, and inverted in a vessel, nearly full, of the same metal, to be placed in the positions represented in the drawing. The upper surfaces of the columns of mercury in each tube, will be found always coincident with the same horizontal plane, however different may be the angle which they make with the horizon. And the horizontal plane, in which their surfaces are thus found, will be between 28 and 31 inches above the surface of the mercury in the vessel. The line, *L*, with which the mercury in each of the tubes is on a level, represents a cord rendered horizontal, by making it parallel with the surface of the mercury in the reservoir.

*Additional Illustration of Atmospheric Pressure.*

89. I trust that the preceding illustration are well adapted to convey a clear notion of atmospheric pressure; but as it sometimes happens, fortuitously, that when cannot get access to the mind under form, it may reach it in another, even less eligible, I subjoin the following illustration, which, though less amusing, and ciating with it fewer instructive phenomena is more brief, and perhaps equally effective.

90. If a tube, recurved into a crook, and so as to form a syphon, with legs of very unequal length, and both ends have the crook lowered into water, as adjoining figure, the fluid will of course rise within the tube to the same height without. But if, before the crook is in the fluid, it be occupied by mercury, water will enter the tube, only so far as the pressure which it exerts upon the mercury in the short leg of the syphon, is competent to raise the mercury in the long leg.

91. This pressure, or the effort of the water to enter the tube, is obviously measured by the height to which it forces the mercury in the long leg of the syphon, above the mercurial surface in the short leg. This height will of course be greater or less in proportion to the depth to which the surface of the mercury may be sunk. The pressure will also be greater or less, according to the fluid in which it is immersed is heavier.

Hence, as water is about 820 times heavier than air, a depth of 820 inches in air would displace the mercury as much as one inch in water.

92. Let us imagine a tube recurved at one end, similarly to the one represented in the foregoing figure, the crook likewise occupied by mercury, to have the orifice as completely above the atmosphere, as the orifice of the tube is above water in the jar. The mercury, in the short leg of the syphon, thus situated, is evidently exposed to a pressure, caused by the air analogous to that sustained from water, in the case of the tube, as already illustrated; and this pressure would, as in the case of the water, be measured by the rise of the mercury in the long leg of the syphon.

93. Yet to realize this experiment with a syphon reaching above the atmosphere it is obviously impossible; but, as the only motive for giving such a height to the syphon is to render the mercury in the long leg inaccessible to atmospheric pressure, if this object can be otherwise attained, the phenomenon may be exhibited in the case of the atmosphere without any material deviation.

94. In fact, to protect the mercury in the long leg from atmospheric pressure, we have only to seal the orifice of that leg, and, through the orifice of the other, to fill the syphon with mercury, before we place it in a vertical position. We shall find that the pressure of the air on the mercury, in the open leg of the syphon, supports a column of this metal in the other leg of nearly thirty inches, though occasionally varying from 28 to 31 inches.

*Inferences respecting the Weight of the Atmosphere from the preceding Experiments.*

95. Supposing the base of the column of mercury, sustained by the atmosphere, as demonstrated in the preceding articles, were equivalent to a square inch, the weight of the column would be about fifteen pounds. This of course represents the weight of that particular column of air only, whose place it has usurped; for every other superficial inch on the earth's surface, a like column of air, the earth must sustain a pressure from the atmosphere, equal to as many columns of mercury, 30 inches high, as could stand upon it; or equal to a stratum of matter of the height just mentioned, extending all over the surface of the globe.

It has been shown that the heights of heterogeneous fluids, reciprocally resisting each other, are inversely as their gravities; or, in other words, that they are as much lighter as lighter, as much lower as heavier. The height of the column of mercury, by its pressure, elevates the mercury, must, therefore, be as much greater than the height of the column of mercury, as the weight of the mercury is greater than the weight of the air, supposing the air to be of uniform density. Mercury is 1112 times heavier than air, and of course the height of the atmosphere would be (of uniform density)  $11152 \times 30$  inches = 27880 feet; supposing 30 inches to be the height of the mercurial column supported.

Hence the atmosphere, if of the same density throughout as on the surface of the earth, would not extend much above the elevation ascribed to the highest mountains.

But as the pressure of the atmosphere causes its density, it may be demonstrated that the heights increasing in arithmetical progression, the densities will decrease in geometrical progression. Thus at an elevation of three miles, the air being, by observation, half as dense as upon the earth's surface:

At 6 miles it will be $\frac{1}{4}$	At 21 miles it will be $\frac{1}{128}$
9 - - - - $\frac{1}{8}$	24 - - - - $\frac{1}{32}$
12 - - - - $\frac{1}{16}$	27 - - - - $\frac{1}{64}$
15 - - - - $\frac{1}{32}$	30 - - - - $\frac{1}{128}$
18 - - - - $\frac{1}{64}$	

or more than we can render it by the finest air pump. These results have been verified to a considerable extent, by actual observation.

It is reasonable to suppose that there is a degree of rarefaction, at which the weight of the ponderable particles of the air will be in equilibrio with the repulsive power of the caloric united with them. Beyond the distance from the earth's surface at which there should be such an equilibrium, the air could not exist. Hence it is inferred that the extent of our atmosphere is limited.

### Of the Water Pump.

100. The admission of the atmosphere is necessary to the suction of the water from a receiver. Air may be removed from close vessels by the same process. Water rises by the pressure of the atmosphere; air presses out by its own elasticity.

*Mechanism and Action of the Suction Pump rendered evident by means of a Model with a Glass Chamber. Difference between pumping an Elastic Fluid and a Liquid, illustrated by an appropriate Contrivance.*

101. A little suction pump is constructed, with a chamber C C, of glass, which permits the action of its piston, P, and valves to be seen. Below the pump is a brass globe filled with water. This globe communicates with the pump by a tube, rising & descending from the lower part of the pump, through an aperture in the globe, till it nearly reaches the bottom. This tube is luted air-tight into the aperture by which it enters the globe. Its orifice, next the chamber, is covered by a valve opening upwards. In the axis of the piston there is a perforation, also covered by a valve opening upwards.

102. If the piston, P, be moved alternately up and down as usual in pumping, as often as it rises its valve will shut close; so that if nothing passes by the sides of the piston, nor enters into the chamber of the pump from below, a vacuum must be formed behind the piston. Under these circumstances, it might be expected that the water would rise from the globe through the lower valve, and prevent the formation of a vacuum. But being devoid of elasticity, and, therefore, incapable of self-extension beyond the space which it occupies, the water does not rise into the chamber of the pump, so long as by means of the cock, C, of the recurved pipe, P P, communication with the external air is prevented. But if this cock be opened during the alternate movement of the piston, a portion of the water will mount from the globe into the chamber at each stroke of the piston. The opening of the cock permits the atmosphere to press upon the fluid in the globe, and to force it up the tube leading to the pump chamber, as often as the chamber is relieved from atmospheric pressure by the rise of the piston. As soon as the piston descends, the valve over the axis of the tube shuts, and prevents the water from returning into the globe. It is of course forced through the perforation in the piston, so as to get above it.



When the piston rises, the valve over its perforation being shut, it lifts the p of water above this valve until it runs out at the nozzle of the pump; whil chamber, below the piston, receives another supply from the globe. But if aft the water has been pumped from the globe, the pumping be continued *with th closed*, a portion of air will be removed from the globe at each stroke, until the due be so much rarefied, as, by its elasticity, no longer to exert against the closing the tube, sufficient pressure to lift it, and thus to expand into the v formed behind the piston, as often as it rises.

103. The rarefaction thus effected in the air remaining in the globe, is res strikingly evident, by causing the orifice of the curved tube to be under the s of some water in an adjoining vase, while the cock is opened. The water r from the vase into the exhausted globe with great violence; and the exten e rarefaction is demonstrated by the smallness of the space within the globe whic residual air occupies, after it is restored to its previous density by the entran the water.







*Description of a Chemical Implement.*

104. The operation of sucking up a liquid through a quill, arises from the partial removal of atmospheric pressure from within the quill by the muscular power of the mouth. There is a great analogy between the mode in which suction is effected by the mouth, and that in which a liquid is made to rise into the bulb of an implement which I am about to describe, and which is very useful for withdrawing small portions of liquids from situations from which otherwise they cannot be removed without inconvenience.

105. This instrument is constructed by duly attaching a bag of caoutchouc to the neck of a glass bulb with a long tapering perforated stem.

106. In order to withdraw from any vessel into which the stem will enter, a portion of any contained liquid, it is only necessary to compress the bag so as to exclude more or less of the air from within it; then to place the orifice of the stem below the surface of the liquid, and allow the bag to resume its shape. Of course, the space within it becoming larger, the air must be rarefied, and inadequate to resist the pressure of the atmosphere, until enough of the liquid shall have entered to restore the equilibrium of density between the air within the bag and the atmosphere. The air within the bag cannot, however, fully resume its previous density; since the column of the liquid counteracts, as far as it goes, the atmospheric pressure. Indeed, this counteracting influence is so great in the case of mercury, that the instrument cannot be used with

id. It is however the only substance, fluid at ordinary temperatures, which may be drawn up into the bulb of the instrument in question, when furnished with a stout bag.

*Of the Air Pump.**Difference between the Air Pump and the Water Pump.*

The action of the air pump is perfectly analogous to that of the water pump; as no difference between pumping water and pumping air, excepting that which arises from the nature of the fluids; the one being elastic, the other, in common with all fluids, almost destitute of elasticity.

In the air pump, as in the water pump, therefore, there is a chamber, and an upper and lower valve, which operate in the same manner as the valves of the water pump already described.

*Description of a large Air Pump with Glass Chambers.*

The opposite engraving represents a very fine instrument of large size, obtained from Mr. Fizeau, of Paris.

From the figure, it must be evident that this pump has two glass chambers. The lower chamber is unusually large, being nearly three inches in diameter inside. The valve, V, is placed at the end of a rod, which passes through the packing of the upper chamber. Hence, during the descent of the piston, the friction of the packing on the rod, causes it to act upon the valve with a degree of pressure adequate to prevent any escape of air, through the hole which it closes, at the bottom of the chamber. The air included between the piston and the bottom of the chamber, is, by the descent of the piston, propelled through a channel in the axis of the rod, and is forced by a valve opening upwards. When the motion of the piston is reversed, the air cannot, on account of the last mentioned valve, return again into the chamber which the piston leaves behind it. But in the interim, the same friction of the rod, which had caused it to press downwards, has now, in consequence of the reversal of the stroke, an opposite effect, and the valve V is lifted, so that a collar on the upper part of the rod will permit. The rise, thus permitted, is sufficient to allow the air to enter the chamber through an aperture which the valve closes, and which communicates by means of a perforation with a hole in the side of the air pump plate, and of course with the cavity of the receiver, RR, and the plate. The reaction of the air in the perforation and pump chamber

being diminished, the air of the receiver moves into the chamber until the equilibrium of density is restored between the two cavities. The chamber will now be full of air as at first; but the air with which it is replenished is not so dense as that which had existed, before the stroke, in the receiver alone. By the next downward stroke the air which has thus entered the chamber is propelled through the valve in the piston. Another upward stroke expels this air from the upper portion of the chamber; and the valve attached to the rod being again uplifted, the portion of the chamber, left below the piston, is supplied with another complement of air from the receiver: and thus a like bulk of air is withdrawn at every stroke of the pump. We may say a like bulk of air, since the quantity necessarily varies with the density of the air in the vessel subjected to exhaustion. This density is always directly as the quantity of air remaining; of course it finally becomes insignificant. Thus when the quantity in the receiver, is reduced to one-hundredth of what it was at first, the weight removed, at each stroke, will be one-hundredth of the quantity taken at each when the process began.

111. I have explained the action of one chamber only, as that of the other is exactly similar, excepting that while the piston of one descends, that of the other rises.

112. The gauge represented in the engraving, is one which I have contrived as a well known principle. It consists of a globular vessel to hold mercury, supported upon a cock. The mercury is prevented from entering the perforation in the tube by a tube of iron, surmounted by a smaller one of varnished copper, which passes into a Torricellian glass tube till it reaches near the top. The glass tube opens at its lower extremity, under the surface of the mercury in the globe. The exhaustion of this tube, and that of any vessel placed over the air pump plate, proceed simultaneously, and consequently the mercury is forced up from the globe into the tube to an altitude commensurate with the rarefaction.

113. By inspecting a scale, SS, behind the glass tube, the height of the mercury is ascertained. In order to make an accurate observation, the commencement of the scale must be duly adjusted to the surface of the mercury in the globe. Care must be taken that the account it is supported by sliding bands on an upright square bar, between the cylinders.

114. The receiver, RR, represented on the air pump plate, is one which I employ in exhibiting the artificial aurora borealis. The sliding wire, terminating in a ball, enables the operator to vary the distance through which the electrical discharges are induced.

#### *Experimental Illustrations of the Elastic Reaction of the Air.*

*Air occupying a small Portion of a Cavity, rarefied so as to fill the whole Space.*

115. Air is dependent on its own weight for its density, and enlarges in proportion as the space allotted to it is enlarged.

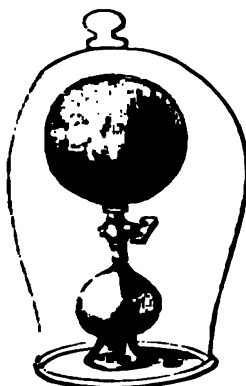


116. The mode in which the air occupying but a small part of a vessel may be rarefied so as to fill the whole cavity, is shown by the experiment represented in the annexed engraving. A bladder is so suspended in a receiver, as that the cavity of the bladder communicates through its own neck with the cavity of the receiver; and such communication exists between the receiver and the space between the bladder and the inside of the vessel.

117. Things being thus situated, and the receiver exhausted, the bladder contracts in consequence of the removal of air from within it, proportionably with the exhaustion of the receiver; for, as the air between the outside of the bladder, and the inside of the receiver no longer resisted, within the bladder, by air of the same density, it expands into the space which the bladder had occupied, so as to reduce it into a very small compass.

118. This cannot excite surprise, when it is recollected that the air, confined between the outside of the bladder and the inside of the vessel, had previously to the exhaustion been condensed, supporting the whole atmospheric pressure, and must of course enlarge itself in proportion to its elasticity, as that pressure is diminished.

*Dilatation of a Caoutchouc Bag by the Rarefaction of confined Air.*



119. The power of any included portion of air to extend itself in consequence of a removal of pressure, is illustrated in another way, by subjecting to a highly rarefied medium a gum elastic bag, its orifice being previously closed, so as to be air-tight. The bag will swell up in a most striking manner, in proportion to the diminution of power in the air without the bag to counteract the reaction of the air within it.

120. The experiment is reversed by subjecting a bag, while inflated, to the influence of a condenser, by which it may be reduced in size more than it had been expanded; the air within the receiver being rendered denser than without.

121. In the adjoining cut, the gum elastic bag is represented as when inflated. The glass represented below the bag, is one which happened to be used as a support when the drawing was made.



*Expulsion of a Liquid by the Rarefaction of Air.*

122. A flask, half full of water, is inverted in another vessel, having some water at the bottom, and both are placed, under a bell glass, on the plate of an air pump. As the bell is exhausted by the action of the pump, the air included in the flask enlarges its bulk, finally occupying the whole cavity, and partially escaping from the orifice through the water in the lower vessel. When the atmosphere is allowed to re-enter the bell, the water rises into the flask, so as to occupy as much more space than at first, as the air occupies less, in consequence of a portion having escaped as abovementioned.



*Experimental Proofs of the Weight of the Atmosphere.*

*Atmospheric Pressure on the Hand.*

123. If, as represented in this figure, the air be exhausted from a vessel covered by the hand, its removal will be found almost impracticable: for, supposing the opening which the hand closes to be equal to five square inches, at 15 lb. per square inch, the pressure on it will evidently be seventy-five pounds.

*Bladder ruptured by the Weight of the Atmosphere.*

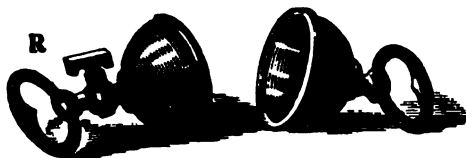


124. Let there be a glass vessel open at both ends, as represented in this figure. Over the upper opening let a bladder be stretched and tied, so as to produce an air-tight juncture. For every square inch of its superficies, the bladder thus covering the opening in the vessel sustains a pressure of about 15 pounds. Yet this is productive of no perceptible effect; because the atmosphere presses upwards against the lower surface of the bladder, as much as downwards upon the upper surface. But if the vessel be placed upon the plate of an air pump, so that, by exhaustion, the atmosphere

ric pressure downwards be no longer counteracted by its pressure upwards, the bladder will be excessively strained, and usually torn into pieces.

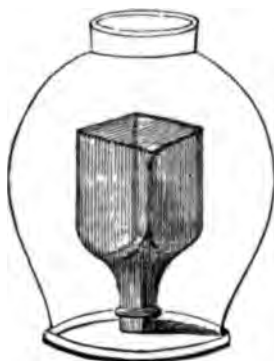
125. When the bladder is too strong to be broken by the unassisted weight of the air, a slight score with the point of a penknife will cause it to be ruptured not only where the score is made, but in various other parts, so that it will, at times, be torn entirely from the rim of the vessel.

*The Hemispheres of Otto Guericke, the celebrated Inventor of the Air Pump.*



126. Two brass hemispheres are so ground to fit each other at their rims as to form an air-tight sphere when united. One of the hemispheres is furnished with a cock, on which is a screw for attaching the whole to the air pump. Being by

these means exhausted, the cock closed, and the ring, R, screwed on to the cock, great force must be exerted, before the hemispheres can be separated.

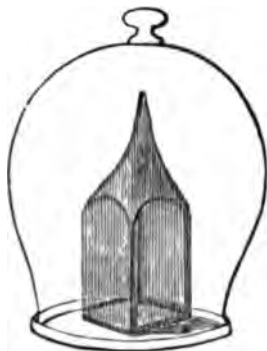


*Bottle broken by Exhaustion of the Air from within.*

127. Proof that a square glass bottle may be broken by atmospheric pressure on the outside, as soon as it ceases to be counteracted by the resistance of the air within.

128. The mouth of a square bottle being placed over the hole in an air pump plate, so as to be sufficiently tight for exhaustion, a few strokes of the air pump, by withdrawing the air from the interior, causes the bottle to be crushed.

129. A stout globular glass vessel, with an aperture at top, is placed over the bottle, to secure the spectators from the fragments.



*Bottle broken by Exhaustion of the Air from without.*

130. The elastic reaction of the air, confined within a square bottle, will burst it, as soon as relieved from the counteracting weight of the atmosphere.

131. If a thin square bottle, so sealed that while unbroken the contained air cannot escape, be placed within the receiver of an air pump, the exhaustion of the receiver will, by removing the pressure which counteracts the elastic reaction of the confined air, cause the bottle to be fractured.

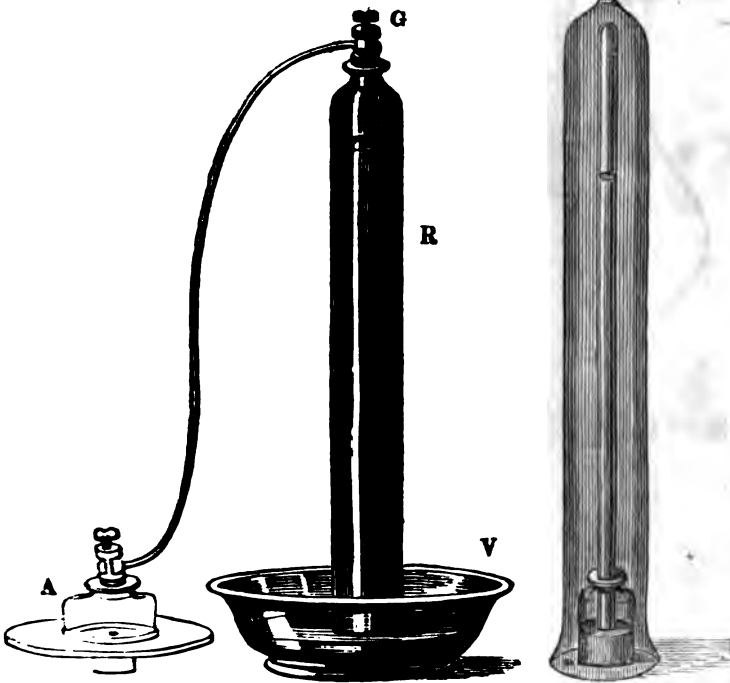
*The Height of the Column of Mercury which balances the Atmosphere, shown by Exhaustion.*

132. R, fig. 1, is a hollow glass cylinder, about 33 inches in height, and  $2\frac{1}{4}$  inches in diameter, into the upper end of which a brass gallews screw, G, is cemented; so that by means of the flexible pipe communicating with the air pump plate, A, the cylinder may be exhausted. The mouth of the cylinder being immersed in mercury in the vase, the metal, as the exhaustion proceeds, rises in the cylinder, until it

more or less nearly to the height at which it stands in a Torricellian tube, say, as the pump may be more or less perfect.

FIG. 2.

FIG. 1.



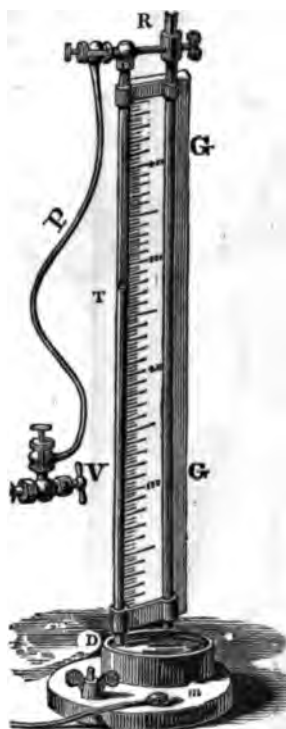
*Barometric Column of Mercury lowered by Exhaustion.*

33. It has been shown that in a tube void of air, a mercurial column may be supported at the height nearly of thirty inches; and this has been alleged to result from the pressure of the atmosphere on the surface of the mercury on the outside of a tube.

34. In order to verify this allegation, let a tube, fig. 2, supporting within it a column of mercury, be placed under a competent receiver upon the air pump plate.

35. It will be found that, as the air is withdrawn from the receiver, the mercury in the tube will subside, and, if the exhaustion be carried far enough, will sink to a level with the mercury on the outside.

36. If, while this experiment is performing, a communication exist between the pump and the cylinder, R, employed in the preceding experiment, the mercury rises in the cylinder, while it falls in the tube; thus proving that the force which is required to remove the air from the outside of the tube and lower the mercury has it is adequate to raise in the cylinder a mercurial column equal in height to that which is reduced.

*Of the Barometer Gauge.*

137. While I am upon the subject of atmospheric pressure, it appears to me expedient to give a description of an instrument which, in several of my illustrations, is employed to ascertain the quantity of air within a receiver.

138. It consists of a barometer tube, 33 inches in height, supported in a vertical position by a pedestal, and a strip of wood, G G. Attached to the latter is a brass scale, by which 30 inches is divided into 500 equal parts. The gauge tube is surmounted by a ferrule and gallews screw, by the aid of which a flexible leaden pipe, P, communicates with the bore of the tube. By means of the valve cock and gallews screw at V, this pipe may be made to communicate also with the cavity to be measured, the valve cock enabling us to suspend the communication when desirable. The lower orifice of the glass tube, T, is covered by mercury in a broad shallow receptacle, D. Supposing the cavity, under these circumstances, to be exhausted, and the communication with the bore of the glass tube open, the extent of the exhaustion, or, in other words, the quantity of air withdrawn, will be exactly in proportion to the rise of the mercury as indicated by the scale; and consequently, reversing the operation, the fall of the mercury, as indicated by the scale, will show the quantity of air which may be introduced. If we count the degrees upwards from the surface of the mercury in the receptacle, D, their number will show the quantity of air withdrawn. If we count the degrees downwards from the level of the top of the mercurial column in the barometer, the number will indicate the exact quantity of gas in the cavity examined. In short, the quantity taken out, or introduced, is always measured by the number of degrees which the mercury rises or falls in

consequence. It is preferable to have two scales, one beginning above, the other below.

139. This gauge may be employed to indicate the quantity of air in any cavity. It only requires accuracy in the divisions of the scale, and in the adjustment of zero to the proper level. As the height of the mercurial column in the barometer varies with those changes of atmospheric pressure which it is employed to indicate, therefore, in counting downwards, care must be taken to place the commencement of the scale on a level with the upper end of a column of mercury in a good barometer, at the time. To facilitate this adjustment, I have occasionally placed a Torricellian tube by the side of the gauge tube. The top of the column of the mercury in the Torricellian tube is then the proper point for the upper zero. As the strip of wood to which the scale is attached slides upon the iron rod, R, the scale may be fixed at a proper height by a set screw.\*

140. As a perfect vacuum cannot be produced by means of an air pump, in order to wash out of a receiver all traces of atmospheric air, it is necessary that portions of the gas to be substituted should be repeatedly introduced, and as often removed by exhaustion.†

141. The rise of the mercury in the tube, by diminishing the quantity in the receptacle, D, will cause the surface of it to be lower; but the breadth of this vessel is so great, and the descent of the mercurial surface in it so inconsiderable, that no error worthy of attention is thus produced.

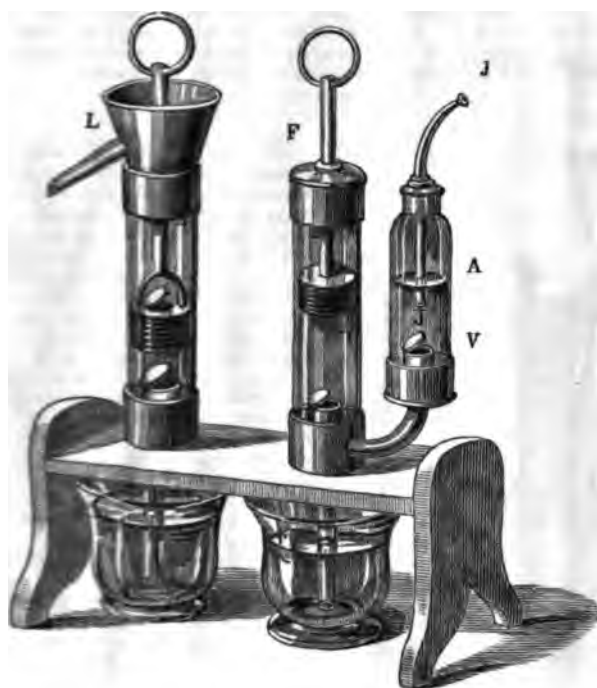
142. It is proper to mention that the cavity of the tube ought to be so small in proportion to that of the receiver, as to create no error worthy of attention.

\* Both the gauge tube and the rod, R, should be longer than they are represented in the figure.

† One gas may be employed to wash another out of a cavity, in a mode analogous to that in which water may wash out alcohol, or alcohol water.



*Apparatus for illustrating the Difference between the Lifting and Forcing Pumps.*



143. The process by which the water is drawn into the chamber is the same in both of the forcing as in that of the lifting pump. In the lifting pump, L, the water which has entered the chamber during the ascent of the piston, passes through a pipe during its descent, and is lifted by it when the motion is reversed. In the forcing pump, F, the piston, being imperforate, forces, in descending, the water into an adjacent air vessel, A, whence its regress is prevented by a valve, V. The motion being repeated, the water accumulates in the air vessel, compressing the contained air until it reacts upon the water with sufficient force to cause an emission of the liquid through the jet pipe, J J, commensurate with the supply.

#### *Of Condensation.*

144. It has been shown that, in consequence of the elasticity of the air, the quantity of the fluid in any close vessel, may be diminished until the residual portion, by the action of the air pump, become too rare to escape in opposition to the slight resistance made by the valves. It remains to show that, in consequence of the same property, by an operation the converse of that of the air pump, the air in any adequate vessel may be made many times more dense than it would otherwise be.

#### *Of the Condenser.*

145. The instrument employed for the purpose of condensing air is called a condenser.

146. The air pump was illustrated by its analogy with the suction pump. There is the same analogy between the condenser and the forcing pump. In the air pump, the valve between the chamber and receiver opens towards the chamber; in the case of the condenser a corresponding valve opens towards the receiver.

147. Besides the valve thus placed between the chamber and receiver, there is in the pump another valve. In the air pump, the air passes this second valve only

when the piston moves so as to lessen the vacancy between it and the bottom chamber; in the condenser, the air passes only when the piston moves to large the vacancy. In other respects these machines are so much alike, that they might be used for the other. In my experimental illustrations, I shall have to employ instruments which serve either to exhaust or to condense, and the aperture selected for making a communication with the receiver.

FIG. 1.

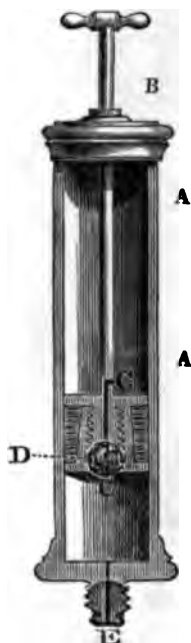


FIG. 2.



148. Fig. 1, in the adjoining engraving, represents a condenser. It consists of a brass cylinder, A A, ground in as to be perfectly cylindrical. A piston, B, is fitted by means of leathers packed between screws, as represented in the figure, and turned on a lathe, so as to enter the chamber with force to considerable force. At the bottom end of the rod, a perforation, C, is seen, which commences at the bottom extremity, rises vertically until it reaches the packing, and then passes on at an angle to its previous direction to the rod of the piston. Just above the packing, a cavity, D, may be formed, which is left for the upper valve. The lower valve is formed of a strip of oil cloth tied over a brass knob representing the cavity.

149. The upper and lower valves are exactly alike; hence, a good idea may be obtained from fig. 2, which is a separate view of the lower valve.

150. The action of the condenser follows. When the piston is drawn up, the air within the chamber gets packed through the perforation, C, into the upper valve, which opens with ease so as to afford a passage. When the piston descends, the air in the lower chamber cannot get by the leather

The upper valve at the same time shuts so as to prevent it from getting to the perforation, C C. It has therefore to proceed through the lower perforation. The piston being drawn up again, the valve at E shuts and prevents a re-entrance of air expelled, while the air of the chamber again gets below the piston as before. Thus, at every stroke, the contents of the chamber are discharged into the receiver, while its retrocession from any receiver into which it is prevented by the valve, E.

151. As the quantity of air in the vessel increases, the force requisite to push the piston home becomes greater; and it has to descend farther, ere the air in the chamber exceeds in density that in the receiver, so far as to open the low

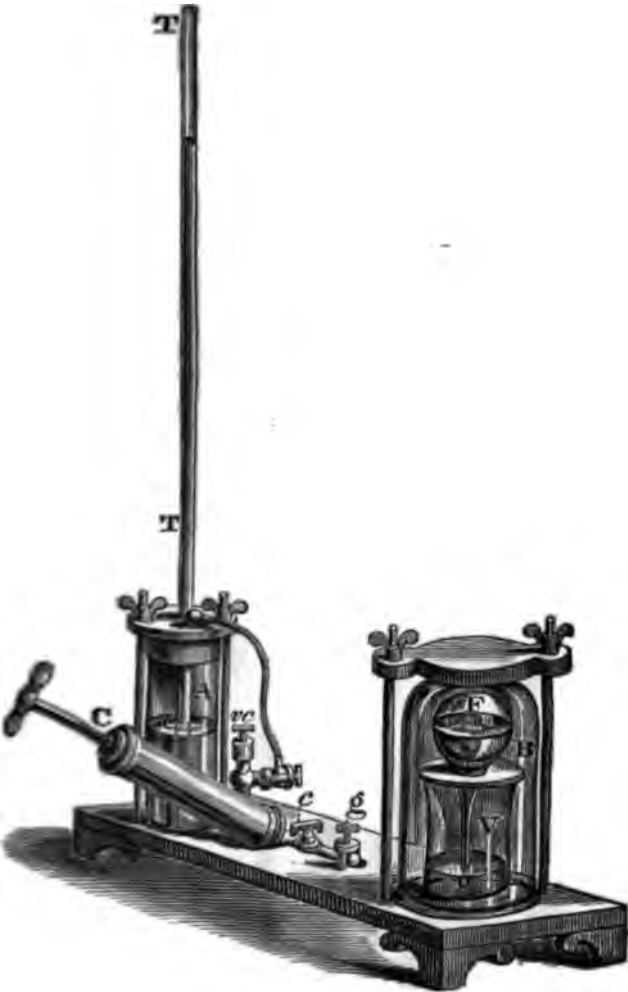
#### *Influence of Pressure on the Bulk of Air, and of its Density on its Resistance.*

152. *Air lessens in bulk as the pressure which it sustains augments; and its resistance arising from its elasticity is augmented, as the quantity confined in the vessel is increased, or the confining space diminished.*

153. For the illustration of this proposition, I have devised the apparatus represented in the opposite engraving.

154. If mercury be poured into the air-tight vessel, A, through the tube, which passes perpendicularly into this vessel until it touches the bottom, the air in the vessel cannot escape, it is gradually reduced in bulk, but at the same time acts upon the surface of the metallic liquid with a force which becomes proportionally as its bulk is lessened. Hence an increasing mercurial column is upheld, which by its height indicates the resistance. When the air in the vessel has been reduced to half its previous bulk, the height of the mercury in the tube will be about 30 inches, or equal to that of the mercury in the barometer at

*valve for illustrating the Influence of Pressure on the Bulk of Air.*



(Page 28.)



ing the experiment. Thus it is shown, that when air is condensed into half as much it occupies under the pressure of the atmosphere, its reactive power is being adequate to support a column of mercury equal to the pressure of space, in addition to that pressure. It follows that the quantity of air occupying any space is as the pressure, and is always to that of an equal bulk of the air, as the height of the column of mercury which the said air can support in a glass tube, is to the height of the mercury in the barometer: and likewise that the resistance of air increases with the diminution of the including space; versa, that the space which a given weight of air is capable of occupying, is as the pressure increases.

It remains to be shown that the resistance of air to compression increases as density in any space increases.

If, by means of the condenser, C, (the valve cock, *v c*, and the cock, *c*, being as before injected into the vessels, A and B at the same time, it will be found that the liquid in the vase, V, will mount into the flask, F, and that when the pressure is adequate to cause the air in this to be reduced to half its previous volume, the mercury in the tube, TT, will have the same height as in the previous experiment: because the density of the air, and of course its quantity and reactive power, will in one case be no less than in the other.

The communication between the condenser and the receiver, A, is suspended in the first mentioned experiment, by closing the valve cock, *v c*. This cock is during the action of the condenser in the second experiment; and likewise the cock at *c*, which serves to intercept the communication between the receiver and the receiver, B.

#### *Mechanical Action of the Lungs in Respiration illustrated.*

The elevation of the sternum rarefies the air within the cavity of the thorax. As the atmospheric pressure not being adequately resisted, the external air enters through the trachea into the lungs, dilating all the cells. The depression of the sternum and consequent diminution of the cavity cause the air which had entered, or an equivalent portion, to flow out. For the illustration of the process described, I have contrived the apparatus represented below.

A tall receiver, R, with an orifice, O, is placed in a globe containing water,



so that about two-thirds of the receiver are occupied by this liquid, the remainder with air, whilst a bladder is so suspended from the orifice as not to touch the

160. The atmosphere has access to the cavity of the bladder through its neck through the orifice O of the receiver, but not to the space A, between the outside of the bladder and the inside of the receiver.

161. It may be assumed as an obvious consequence of the preceding experiments (154, 156) that the pressure, exerted by any given quantity of air, is inversely confining space; or in other words, that the pressure increases as the space is diminished and diminishes as the space enlarges.

162. When a cavity to which the atmosphere has no access is enlarged, the density of the contained air is proportionably diminished. When any cavity is diminished, the density of the contained air is proportionably increased. But if the atmosphere, meanwhile, have access to the cavity, it will by its influx or efflux to preserve the equilibrium of density and pressure between the air of the cavity and the external medium. These consequences are well known to ensue, from the alternate enlargement and diminution of capacity, during the working of an air pump, a condenser, or bellows.

163. In like manner the elevation of the receiver, R, enlarging the cavity of it unoccupied by water, causes the air to rush in through the orifice, O; and the reversal of the motion, reducing the cavity, causes the air to rush out through the same aperture. The bladder is so situated as to receive all the air that enters, and supply all that is expelled. Hence when the receiver is lifted, the bladder is inflated, and when lowered to its previous position, the bladder resumes its original dimensions.

164. Supposing the space, A, between the outside of the bladder and the inside of the receiver, to represent the space between the outside of the lungs and the inside of the thorax, the cavity of the bladder representing the cavities of the lungs, the orifice, O, performing the part of the trachea and nostrils, the explanation, given, will be as applicable to the apparatus by which nature enables us to breathe as to that employed in the preceding illustration.

#### EXPANSION OF ELASTIC FLUIDS.

165. Having by means of the preceding digression explained the nature and extent of atmospheric pressure, we shall proceed to show the important influence exerted by it in all chemical processes in which elastic fluids are concerned.

166. It has been demonstrated (54) in illustrating the principle of Sanctorio's thermometer, that the bulk of air in any space varies with the temperature.

167. It has been shown that the same effect may be produced by variations in atmospheric pressure. (119, 120, 122.)

168. It follows that the volume of elastic fluids is inversely as the pressure and directly as the heat. In other words, the less the pressure and the greater the heat, the larger their bulk; and vice versa, the less the heat, the greater the pressure, the less their bulk.

169. Agreeably to the observations of Dalton, Gay-Lussac, and Berzelius, 1000 parts of atmospheric air, in rising from the temperature 0° to 212°, will expand so as to measure 1375 parts nearly, or,  $\frac{1}{4} \frac{1}{8}$ th of its bulk which it would have at 32°, for each degree of heat which it receives.

Having, therefore, any given bulk of dry air, 100 cubic inches for instance at  $60^{\circ}$ , to find its bulk at any other temperature, suppose at  $80^{\circ}$ , in the first place consider that 480 parts at  $32^{\circ}$  would at  $60^{\circ}$ , be one part for every degree above  $32^{\circ}$ , be 508 parts; and would by the same increase, become at  $80^{\circ}$ , 528 parts. But if 508 parts at  $60^{\circ}$  become 528 at  $80^{\circ}$ , what will 100 parts at  $60^{\circ}$  become when heated

$$508 : 528 :: 100 : 103.9$$

It has been inferred by the same distinguished philosophers, that all substances, whether gases or vapours, are expanded by heat at the same rate as dry atmospheric air, if they be not in contact with any other matter, in the liquid or solid state, which by vaporizing or condensing may vary the result.

### *Theory of Expansion.*

The expansion of matter, whether solid, liquid, or æriform, by an increase of temperature, may be thus explained.

In proportion as the temperature within any space is raised, there is more caloric in the vicinity of the particles of any mass contained in that space. The more caloric in the vicinity of the particles, the more they combine with them; and in proportion to the quantity of caloric combined, will they be actuated by that reciprocally repellent power, in proportion to its intensity, regulates their distance from each

other. There may be some analogy between the mode in which each atom is surrounded by the caloric which it attracts, and that in which the earth is surrounded by the atmosphere; and as in the latter case, the density in the former, the density is inversely as the square of the dis-

tance. At a height at which the atmospheric pressure does not exceed a square inch, suppose it to be doubled, and supported at that increased pressure by a supply of air from some remote region; is it not evident that a condensation would ensue in all the interior strata of the atmosphere, until the pressure would be doubled throughout, so as to be equal to the terrestrial surface, 30 pounds, instead of the present pressure of 15 pounds? Yet the pressure at the point from which the change would originate would not exceed two grains per square inch.

In the same manner, it may be presumed that the atmospheres of caloric are increased in quantity and density about their respective atoms, by a decrease in the caloric tension of the external medium.

*Illustration that Atmospheric Pressure opposes and limits Chemical Action, where Elastic Fluids are to be generated or evolved.*

### *Of Vaporization.*

III. Water would boil at a lower temperature than it does, if the atmospheric pressure was lessened; for when it

has ceased to boil in the open air, it will begin to boil again in an exhausted receiver. Those who ascend mountains find that for every 530 feet of elevation, the boiling point is lowered one degree of Fahrenheit's thermometer. It is, in fact, lowered or raised  $\frac{1}{1000}$ th of a degree for every tenth of an inch of variation in the height of the mercury in the barometer.



*Ebullition from diminished Pressure.*

178. The adjoining figure represents a vessel of water boiling within a receiver, in consequence of the diminution of pressure by exhaustion.

*Culinary Paradox.—Ebullition by Cold.*

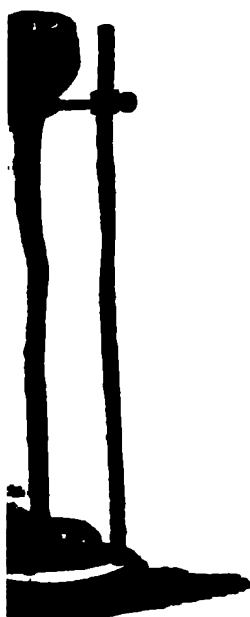


179. A matrass, half full of water, being heated until all the contained air is superseded by steam, the orifice is closed so as to be perfectly air-tight. The matrass is then supported upon its neck, in an inverted position, by means of a circular block of wood. A partial condensation of the steam soon follows from the refrigeration of that portion of the glass which is not in contact with the water. The pressure of the steam upon the liquid of course becomes less, and its boiling point is necessarily lowered. Hence it begins again to present all the phenomena of ebullition, and will continue boiling sometimes for nearly an hour.

180. By the application of ice, or of sponge soaked in cold water, the ebullition is accelerated; because the aqueous vapour which opposes it, is in that case more rapidly condensed; but as the caloric is at the same time more rapidly abstracted from the water by the increased evolution of vapour to replace that which is condensed, the boiling will cease the sooner.



*Improved Apparatus for showing the Calinary Paradox.*



181. This figure illustrates a new and instructive method of effecting ebullition by cold.

182. The apparatus consists principally of a glass matras, with a neck of about three feet in length, tapering to an orifice of about a quarter of an inch in diameter. The bulb is bulged inwards in the part directly opposite the neck, so as to create a cavity capable of holding any matter which it may be desirable to have situated therein. In addition to the matras, a receptacle holding a few pounds of mercury is requisite. The bulb of the matras being rather less than half full of water, and this being heated to ebullition, the orifice should be closed by the finger, defended by a piece of gum-elastic, and depressed below the surface of the mercury; the whole being supported as represented in the figure. Under these circumstances, the mercury rises as the temperature of the water declines, indicating the consequent diminution of pressure within the bulb. Meanwhile, the decline of pressure lowering the boiling point of the water, the ebullition continues till the mercury rises in

and nearly to the height of the mercury in the barometer.

83. By introducing into the cup formed by the bulging of the bulb, cold water, alcohol, ether, or ice, the refrigeration, the diminution of pressure, the ebullition, are all simultaneously accelerated; since these results are reciprocally dependent on each other.

*Experimental Proof that some Liquids would be permanently æriform, if Atmospheric Pressure were removed.*

184. The power of certain liquids, common ether for instance, to assume in vacuo, at ordinary temperatures, the æriform state, in opposition even to the pressure of a column of mercury, may be shown by the following experiment.

185. A glass funnel is ground to fit air-tight into the neck of a glass decanter, so that the stem of the funnel may reach nearly to the bottom of the decanter, as represented in the adjoining cut. The decanter is filled with mercury, with the exception of a small portion of the neck, which is occupied by ether. The stem of the funnel is then introduced into the neck of the decanter, so as to be air-tight; and the whole being included in a receiver, the air is withdrawn by a pump. The ether converted into vapour will force the mercury to rise from the decanter, through the stem, into the wider part of the funnel.



186. *Rationale.*—The attraction between the ponderable particles of the æther, and those of caloric, can be indulged only in opposition to the repulsive power of the latter; since one tends to rarefy the caloric,

the other to condense it into the limited space occupied by the ether follows that the caloric cannot combine with the ponderable matter to the point at which the repulsive power becomes equal to the attractive; the repulsion exercised by the same number of particles of caloric is greater as the space is less, and vice versa. The larger, therefore, the space occupied by the ponderable particles of the ether, the more they may combine with them, without rendering its reciprocally repulsive paramount to its attraction for them.

187. The removal of atmospheric pressure, by allowing the ponderable particles to occupy a larger space, enables them to combine with that additional quantity of caloric which is necessary to the æriform state.

188. This explanation may, of course, be extended to the ebullition of other liquids in vacuo, at temperatures lower than those at which they boil in the air. It is obviously applicable to the two preceding illustrations.

#### *Boiling Point elevated by Pressure*

189. Into a small glass matrass, with a neck of about an inch and a half in diameter and a bulb of about a quarter of an inch in diameter, introduce nearly half as much ether as will fill it. Closing the orifice with the thumb, hold the bulb over the flame of a spirit lamp, with an effort of the generated vapour to escape being difficult to resist. Removing the matrass to a sufficient distance from the lamp, lift the thumb from the orifice. The ether, previously in equilibrium, will rise up in a foam, produced by the rapid extrication of its vapour.

190. This experiment may be performed with less risk, by plunging the matrass in hot water instead of heating it by a lamp.

191. Having supplied a small flask with a quantity of mercury, sufficient to cover the bottom to about an inch in depth, let there be a glass tube so introduced through the neck, and luted air-tight, as to reach nearly an inch below the mercurial surface. The flask thus prepared, be duly heated, the ether proportionably vapourized, and the generated pressure pressing on the mercury, will cause a column of metallic liquid to rise within the tube, and thus indicate and measure the pressure. It is necessary to discontinue the heat, when the mercurial column approaches the upper orifice of the tube, in order to prevent the metal from overflowing.

187

187

187

187

187

187

187

187

187

187

187

***High Pressure Boiler.***



**(Page 35.)**

### *High Pressure Boiler.*

*III. That the temperature of steam increases with the pressure, may be demonstrated by means of a small boiler, such as is represented in the opposite engraving.*

182. A glass tube, of about five feet in height, and of half an inch in bore nearly, is secured into an aperture in a very strong iron boiler, so as to be air-tight, and so as to be concentric with the axis of the boiler. Within the boiler the tube descends in such manner as to pass through the water with which it is supplied, and to terminate close to the bottom, beneath a small quantity of mercury purposely introduced. On the opposite side of the boiler, a tube, not visible in the engraving, descends into it. This tube consists of about two inches of a musket barrel, and is closed at bottom. The object of it is to contain some mercury, into which the bulb of a thermometer may be plunged for ascertaining the temperature.

183. When the fire has been applied during a sufficient time, the mercury will rise in the glass tube so as to be visible above the boiler; and continuing to rise during the application of the fire, it will be found that, with every sensible increment in its height, there will be a corresponding rise of the mercury in the thermometer.

184. In front of the tube, as represented in the figure, there may be observed a safety valve with a lever and weight for regulating the pressure. It has been found that, when the effort made by the steam to escape, in opposition to the valve thus loaded, is equal to about fifteen pounds for every square inch in the area of the aperture, the height of the column of mercury, CC, raised by the same pressure, is about equal to that of the column of this metal, usually supported by atmospheric pressure in the tube of a barometer.

185. Hence the boiler, under these circumstances, is conceived to sustain an unbalanced pressure equivalent to one atmosphere; and for every additional fifteen pounds per square inch, required upon the safety valve to restrain the steam, the pressure of an atmosphere is alleged to be added. To give to steam at 212 degrees, or the boiling point, such an augmentation of power, a rise of 36 degrees is sufficient, making the temperature equal to 248 degrees. To produce a pressure of four atmospheres about 293 degrees would be necessary. Eight atmospheres would require nearly 343 degrees.

187. When by means of the cock an escape of steam is allowed, a corresponding decline of the temperature and pressure ensues.

188. If the steam, as it issues from the pipe, be received under a portion of water of known temperature and weight, the consequent accession of heat is surprisingly great, when contrasted with the accession of weight derived from the same source. It has in fact been ascertained that one measure of water, converted into aqueous vapour, will, by its condensation, raise about ten measures of water in the liquid form one hundred degrees.

### *Of the Incompetency of a Jet of High Steam to scald at a certain Distance from the Aperture.*

189. Much attention has been excited by the observation, that the hands may be enveloped in a jet of vapour from a high pressure boiler without

inconvenience, at a certain distance from the aperture through which escapes.

### *Experimental Demonstration.*

200. The fact that the hand may be immersed without injury in a jet of steam while issuing from a boiler not too near the aperture, experimentally demonstrate

201. *Rationale.*—Since the temperature, density, and pressure, form the distinguishing attributes of high steam, cannot be sustained out of confinement, steam ceases to be *high steam* as soon as it is liberated. Consequently, a jet from a high pressure boiler is essentially no more than a copious jet of aqueous vapour at the heat of boiling water.

202. The only distinguishing characteristic, derived from its previous superior temperature and density, is a greater velocity of efflux. Without any superiority of temperature, the high pressure jet is propelled in the atmosphere with a momentum, which cannot be given to low steam. Hence the rapid refrigeration to which the former is subjected, at a sufficient distance from the place of its efflux to admit of an extensive diffusion in the atmosphere.

*Illustration of the Process by which Thermometers are supplied with the Liquid in their construction.*



203. A globe, with a long cylindrical neck, situated as in the preceding and containing a small quantity of water, being subjected to the flame of a lamp, the water, by boiling, will soon fill the cavity of the globe and neck with steam. When this is accomplished, bubbles of air will cease to escape from the orifice of the neck through the water in the vase.

204. The apparatus being thus prepared, on removing the lamp, the water will quickly rush from the vase into the vacuum arising from the condensation of the steam within the globe.

*Explosive Power of Steam.*



205. If a glass bulb, hermetically sealed while containing a small quantity of water be suspended by a wire over a lamp flame, an explosion soon follows, with a violence and noise which are surprising, when contrasted with the quantity of water by which they are occasioned.

206. *Rationale.*—Supposing that the bulb were, in the first instance, merely filled with steam, without any water in the liquid form, the explanation of this phenomenon would be comprised in the theory of expansion, already suggested. (178.) In that case, the effort of the steam to enlarge itself, would be nearly in direct arithmetical proportion to the temperature; but water being present in the liquid form, while the expansive power of the steam, previously in existence, is increased, more steam generated with a like increased power of expansion. It follows that the amounts of heat being in arithmetical proportion, the explosive power of confined vapour will increase geometrically, being actually doubled as the temperature is augmented  $36^{\circ}$ . (196.)

*rotting Experiments with respect to Vaporization under extreme Pressure, by M. Cagniard de la Tour, and Mr. Perkins.*

207. Agreeably to some experiments performed by M. Cagniard de la Tour, in which liquids were exposed to heat in very stout tubes, vaporization was performed in a space which was to that previously occupied,—

in the case of	{	Ether, as 2 to 1, producing a pressure of 33 atmospheres.
		Alcohol, as 3 to 1, producing a pressure of 119 atmospheres.
		Water, as 4 to 1, producing a pressure greater than that caused by the alcohol.

208. Mr. Perkins alleges that a small iron boiler of great strength may be heated hot while holding a portion of water, and that if, under these circumstances, an aperture be opened of  $\frac{1}{2}$  of an inch in diameter, the steam will not escape, although a reduction of temperature, it will rush out with great violence.

209. It was inferred that the repulsion between the particles of the caloric in union with the water, and those in union with the metallic ring bounding the aperture, was paramount to the pressure tending to produce the expulsion of the steam.

210. I am unable to reconcile this experiment with one which I performed by exposing iron wire to incandescence, in a forge fire, a tube of iron, of which the bore was less than  $\frac{1}{2}$  of an inch, while, by means of a cock, a communication with a high pressure steam was made. Under these circumstances, the steam was not prevented from passing through the pipe.

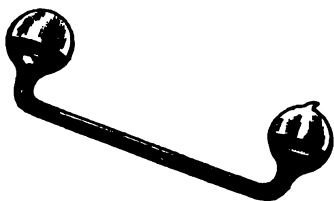
211. It appears to be sufficiently proved that the quantity of caloric combined with an weight of steam is always the same, whatever may be its temperature; the latent heat increasing and the latent heat diminishing as the density and pressure augmented.

*Cold and Cloudiness arising from Rarefaction.*

212. Instant rarefaction in the air of a receiver is usually indicated by a cloud, which appears when the exhaustion has proceeded beyond a certain point. A thermometer placed in the receiver, shows that a decline of temperature

accompanies this phenomenon. We may, therefore, infer that the cloud is the consequence of refrigeration. If the suggestions be correct which were made (*Theory of Expansion*, 175) respecting the mode in which caloric exists in atmosphere, around the particles of ponderable matter, it will not be difficult to understand why æriform fluids should absorb more caloric, in proportion as their constituent particles are enabled, by a diminution of pressure, to become more remote. Hence, by rarefaction, the capacity of air is increased, and cold is produced, which condenses the aqueous vapour until its sensible heat is restored by an accession of caloric from the surrounding medium. (184.)

*Cold produced by the Palm Glass.*



213. In forming the bulbs severally at the ends of the glass tube represented in this figure, one is furnished with a perforated projecting beak. By warming the bulbs, and plunging the orifice of the beak into alcohol, a portion of this liquid enters, as the air within contracts in returning to its previous temperature. The liquid, thus introduced, is to be boiled in the bulb which has no beak, until the whole cavity of the tube and of both bulbs, not occupied by liquid alcohol, is filled with its steam. While in this situation, the end of the beak is to be shortened and sealed, by subjecting it to the flame excited by a blowpipe.

214. As soon as the instrument becomes cold, the steam, which had filled the space vacant of liquid alcohol, condenses, and with the exception of a slight portion of vapour, which is always emitted by liquids when relieved from atmospheric pressure, a vacuum exists within the bulb.

215. The instrument, thus formed, has been called a palm glass; because the phenomenon which it exhibits is seen by grasping one of the bulbs, so as to bring it completely into contact with the palm of the hand. One of the bulbs being thus situated, and while surcharged with the alcohol, and held in the position represented in the figure, both the liquid and vapour are propelled from it into the other bulb. This phenomenon combines the characteristics of the differential thermometer, (89,) with those of the culinary paradox, (179,) being the joint effect of the expansion, and evolution of vapour, in one part of the apparatus, and its contraction and condensation in another. The phenomena are precisely similar, whether we warm the lower bulb, or cool the upper one by means of ice. The motive for recurring to the experiment here is to state that, as soon as the last remnant of the liquid is forced from the bulb in the hand, a striking sensation of cold is experienced by the operator.

216. This cold has been attributed generally to an increase of the capacity of the residual vapour for caloric in consequence of its attenuation. The analogy is evident between this phenomenon and that above described, as taking place in the receiver of an air pump; in either case refrigeration results from a diminution of density.

*Cold consequent to relaxation of Pressure.*

217. Cold is produced whether a diminution of density arise from relieving condensed air from compression, or from subjecting air of the ordinary density to rarefaction. A cloud similar to that which has been described as arising in a receiver partially exhausted, may usually be observed in the neck of a bottle recently uncorked, in which a quantity of gas has been evolved in a state of condensation by a fermenting liquor.





218. The apparatus represented in the annexed figure, shows the influence of relaxed pressure on the capacity of air for heat and moisture.

219. A glass vessel with a tubulure and a neck has an air thermometer fastened air-tight by means of a cork into the former, while a gum-elastic bag is tied upon the latter. Before closing the bulb, the inside should be moistened. Under these circumstances, if the bag, after due compression by the hand, be suddenly released, a cloud will appear within the bulb, adequate, in the solar rays, to produce prismatic colours. At the same time the thermometer will show that the compression is productive of warmth, the relaxation of cold.

220. The cloud which has been shown to arise (212.) in air suddenly rarefied, has been much insisted upon of late, by Mr. Epp, as illustrating a meteorological process, which he considers as the principal cause of rain storms. This induced me to make some experiments in order to elucidate this subject.

Two globes, each containing about a cubic foot of space, furnished with bars and hygrometers, were made to communicate, respectively, with perfectly dry air, and of air replete with aqueous vapour.\* The cold, produced by any degree of rarefaction, appeared to be the same, whether it was in the one state or the other; provided that the air, replete with aqueous vapour, was not in contact with liquid water in the vessel subjected to exhaustion. If water was present, in consequence of the formation of additional vapour, and heat absorption of caloric, the cold produced was nearly twice as great as when the air was not in contact with liquid water; being nearly as 9 to 5.

Under the circumstances last mentioned, the hygrometer was motionless; when no liquid water was accessible, the space, although previously saturated with vapour, by the removal of a portion of it together with the air which is removed by the exhaustion, acquires a capacity for more vapour; and hence the air, by an abstraction of one-third of the air, revolved more than sixty degrees dryness. But when a smaller receiver (after being subjected to a few inches of pressure of about ten inches of mercury, so as to cause the index of pressure to move about thirty-five degrees towards dryness) was surrounded with mixture, until a thermometer in the axis of the receiver stood at three degrees below freezing, the hygrometer revolved towards dampness, until it went on degrees beyond the point at which it rested when the process commenced. It appears, therefore, that the dryness produced by the degree of rarefaction is more than counterbalanced by a freezing temperature.

As respects the heat imparted to the air above mentioned, the fact, that the rarefaction in the case of air replete with vapour, and in that of anhydrous air, was equally great, and that when water was present the cold was greater than when it was not, led to the idea, that the heat arising under such circumstances is of much efficacy in augmenting the buoyancy of an ascending column of air. But when, by an appropriate mechanism, the refrigeration was measured by means of pressure at the moment when the exhaustion was arrested, and the thermometer had become stationary, it was found *ceteris paribus*, that the pressure arising from cold was at least one-half greater in the anhydrous air, than in the air replete with vapour. This difference seems to be owing to the latent heat made by the contained moisture, or transferred from the apparatus.

\* The hygrometers were constructed by means of the beard of the *avena sensitiva*, and the cold was noted out.

rated by its intervention, which checks the refrigeration; yet, ultimately, the whole of the moisture being converted into vapour, the aggregate refrigeration does not differ in the two cases.

225. Agreeably to Dalton's tables, at  $70^{\circ}$  the quantity of moisture in 31 grains 100 cubic inches of air, is 551-1000ths of a grain. The space allotted to this weight of vapour being doubled, it would remain uncondensed at  $45^{\circ}$  F., being associated with the same weight, but double the volume, of air; but at  $32^{\circ}$ , notwithstanding the doubling of the space, only 356-1000ths of a grain would remain in the aerified state; of course  $551 - 356 = 195$ -1000ths, or nearly 2-10ths of a grain, would be precipitated.

226. The latent heat given out by the condensation of this vapour, would heat, it is well known, 1000 times its weight of water, or 195 grains, one degree; or grains  $195$ -31ths  $= 6.29$  degrees; and as the capacity of air for heat is only one-fourth of that of water, it would heat 31 grains of air  $6.29 \times 4 = 25.16$ , or near  $25^{\circ}$  F. As air, at  $32^{\circ}$  F., expands 1-480ths for each additional degree, the difference of bulk, arising from the heat received, as above calculated, would be  $25$ -480ths, 1-19ths nearly.

227. When air, replete with aqueous vapour, was admitted into a receiver partially exhausted, and containing liquid water, a copious precipitation of moisture ensued, and a rise of temperature greater than when perfectly dry air was allowed to enter a vessel containing rarefied air in the same state. In the instance first mentioned, a portion of vapour arises into the place of that which is withdrawn during the partial exhaustion. Hence when the air, containing its full proportion of vapour, enters, there is an excess of vapour which must precipitate, causing a condensation and an evolution of latent heat from the aqueous particles previously in the aerified state. As the enlargement of the space occupied by a sponge, allows, proportionally, a larger quantity of any liquid to enter its cells, so any rarefaction of the air when in contact with water, consequent on increase of heat or diminution of pressure, permits a proportionably larger volume of vapour to associate itself with given weight of the air. When, subsequently, by the afflux of wind replete with aqueous vapour, the density of the aggregate is increased, a portion of the vapour equivalent to the condensation must be condensed, giving out latent heat, except so far as the heat thus evolved, being retained by the air, raises the dew point.

228. Hence, whenever a diminution of density of the air inland causes an influx of sea air to restore the equilibrium, there may result a condensation of aqueous vapour, and evolution of heat, tending to promote an ascending current. This process being followed by that which Mr. Espy has pointed out, of the transfer of heat from vapour to air, during its ascent to the region of the clouds, and consequent precipitation of moisture, is probably among the efficient causes of those non-electrical storms, during which water from the Gulf of Mexico, or from the Atlantic, is transferred to the soil of the United States.

### *Of the Influence of the Atmosphere in promoting Evaporation.*

229. It has been seen that by its pressure the atmosphere opposes vaporization; yet a free access of air is found indispensable in the desiccation of hay, or in the evaporation of water or other solvents. It was at one time generally conceived that evaporation resulted from an affinity between the liquid and the air, analogous to that between water and sugar, or alcohol and resin; but in consequence of the observations of several distinguished philosophers, a different view of this subject has been latterly entertained. It has in fact been ascertained that the quantity of aqueous vapour, in any space having sufficient access to liquid water, is always directly as the temperature, whether there be a plenum or a vacuum, or whatever may be the density of the air simultaneously present.

229. It has been shown that a current of atmospheric particles promotes evaporation only by removing the necessity to which the vapour is otherwise exposed, of diffusing itself through atmospheric interstices to a greater distance.

231. Nevertheless, it appears to me that the influence of a current of atmospheric air, in promoting evaporation, is greater than can be reasonably thus accounted for.

232. It is difficult to conceive that the elements of atmospheric air should have no affinity for those of liquids; or that, if such affinity exist, it should not promote the process of evaporation. Nothing can be more certain than that evaporation is accelerated in proportion to the extent to which contact may be induced between the æri-form and liquid particles. For when surfaces, moistened with such volatile liquids as sulphuret of carbon, or the more volatile ethers, are exposed to the wind, or to a blast, intense cold is produced by the accelerated evaporation. It is well known that the direction of the wind becomes evident from the sensation of coldness, experienced in that part of the wetted finger on which it blows. With the refrigerating influence of a breeze, when the skin is moistened by perspiration, we are all familiar.

233. The processes of evaporation, and vaporization in the sense of ebullition, cannot be confounded in practice, however they may be identified agreeably to prevailing theories. In either case, heat is requisite, though much less is necessary in that of evaporation; but other things being equal, the process last mentioned, is accelerated in proportion to the extent of surface exposed to the air, while ebullition takes place in proportion to the surface exposed to the fire, without access of air. It only requires that the vapour generated should have an aperture sufficient to allow of its escape, without increase of pressure. Hence evaporating vessels are made broad and shallow, while boilers may be made deep with narrow openings.

*Cold produced by the Evaporation of Ether when accelerated by a Current of Air.*

234. The cold, produced by evaporation accelerated by a current of air, may be advantageously shown by subjecting a thermometer bulb simultaneously to a jet of ether,

and a blast from a bellows, so that the aërial and ethereal particles may be thoroughly mingled just before reaching the bulb. Water may be frozen in a bulb thus refrigerated.

235. Agreeably to the principle above illustrated, (217) that when air is liberated from a state of compression, cold ensues, I have lately contrived a new mode of exhibiting the vaporization of ether, so as to freeze water on a more extensive scale, and on a much more striking manner than heretofore. Between the lower part of a very strong vessel of sheet iron, capable of holding 40 gallons, and the "hydrant" pipes by which our city is supplied with water, a communication is made by means of a pipe and cock, so as to be opened or closed at pleasure. The vessel is previously filled with air, by allowing it to discharge any water which it may hold through a cock. Under these circumstances, on opening the communication with the hydrant pipes, the air within the vessel may be subjected to a pressure of more than one atmosphere. (154.) If by means of a suitable leaden pipe, furnished with a cock, and terminating with a capillary orifice, the air be allowed to blow into some ether and water contained in a thin capsule, the ether will be rapidly vaporized, and the water soon frozen.

236. In this experiment, in lieu of hydric (sulphuric) ether, we employ the new form of hyponitrous ether which I have lately discovered, the congelation will be more rapidly accomplished.

237. It will hereafter be shown, that, by analogous causes, when solid carbonic acid is thrown into ether, a refrigeration is produced by which mercury may be rapidly frozen.

#### *Definition of Vapour by Berzelius.*

238. Berzelius objects to the use of the word vapour as implying a condensable aëriiform fluid. He uses it in the sense in which English authors employ the word fog, or cloud. Vapour and steam were originally, and still are used in this sense, yet the fluid which is used to propel steam engines, and to which they owe their distinguishing name, can only consist of water in the aëriiform state in which it is by the distinguished Swede designated as aqueous gas. Johnson defines steam to be the smoke or vapour of any thing hot and moist. Of course steam smoke and vapour have in some cases been used synonymously. I have elsewhere mentioned that before Black's discoveries and inferences were published, atmospheric air was the only aëriiform fluid whose existence was recognised. Hence the use of the words steam and vapour has grown with our knowledge, and consequently the names applied to visible steam or vapour have been extended to mean the invisible aëriiform fluids from which it is produced by refrigeration. I have some repugnance to designating by a common epithet, permanent gases, and the condensable elastic fluids produced from liquids above their boiling points. I do not see that any disadvantage arises from the customary use of the word vapour to designate the latter.

#### *Of the Opponent Influence of Pressure on the Extrication of Gaseous Substances from a state of Combination.*

239. When one of the ingredients of a solid or liquid is prone to assume the aëriiform state, its extrication will be more or less easily effected, in proportion as the pressure of the air is diminished or increased.

*of Carbonic Acid from (*  
*promoted by Exhausti*

*of Lime subjected to an Acid,*  
*cked by Condensation.*



240. If a tall cylindrical jar, containing a carbonate undergoing the action of an acid, be placed under a receiver, and the air withdrawn by an air pump, the effervescence will be augmented. But if, on the other hand, the same mixture be placed under a receiver, in which the pressure is increased by condensation, the effervescence will be diminished. In the one case, the effort of the carbonic acid to assume the gaseous state is repressed; in the other, facilitated. Hence the advantage of condensation in the process for manufacturing carbonic acid water. Beyond an absorption of its own bulk of the gas, the affinity of the water is inadequate to subdue the tendency of the acid to the aëriform state; but when, by mechanical pressure, a great number of volumes of the gas are condensed into the space ordinarily occupied by one, the water combines with as large a volume of the condensed gas, as if there had been no condensation.

*Improved Apparatus for showing the Influence of Pressure on Effervescence.*

239. A cylindrical receiver, about 30 inches in height, and 3 inches in diameter, is supported on a wooden block, W, between upright iron rods, R.R., each at the lower end, riveted to a plate of iron beneath the block, and, at the upper end, a screw nut and furnished with a nut. By means of these screws and nuts thus formed, and an intervening cross bar, B, a brass disk, D, is pressed upon the rim of the receiver. The disk is so ground to fit to the rim of the glass, as that, with the aid of some beeswax duly softened by heat, an air-tight juncture may be made. In the middle of the disk there is an aperture, from which proceeds a stout tube, with a cock on each side, severally furnished with gallews screws, by means of which lead pipes may be made to communicate with an air pump on one side, and a condenser on the other. The tube is also surmounted by a cock, into which a glass funnel is inserted. Before closing the receiver, some solid carbonate in pieces must be introduced so as to occupy about one-third of the cavity. For this purpose I have employed carbonate of ammonis, calcareous spar in fragments, and latterly clam shells. In either of these substances, carbonic acid and lime are the principal ingredients. The carbonate being introduced, and the disk fastened into its place, as represented in the figure, diluted muriatic acid may be added, by means of the funnel and cock, in quantity sufficient to cover the carbonate.

242. In consequence of the superior affinity of chlorine for the calcium, and of hydrogen for the oxygen, (in the oxide of calcium or lime) the carbonic acid is expelled in the gaseous form, causing a perceptible effervescence or foaming of the liquid. Under these circumstances, by means of the air pump, the atmospheric pressure within the receiver be lessened, the effervescence increases strikingly. On the other hand, if, by closing the communication with the air pump, and opening that with the condenser while this is in operation, the pressure be increased, it will be seen that the effervescence is diminished proportionably.

241. This experiment is much facilitated by the employment of an air pump, which I have contrived, by which we can either exhaust or condense at pleasure.

243. Agreeably to experiments performed by Faraday, when the reaction between an acid and a carbonate is made to take place in a stout tube hermetically sealed, the acid may be separated in the liquid form. According to the more recent observations of Thilorier, this result has been attained upon a large scale, and one portion of the resulting liquid has been found to be partially frozen, by the caloric absorbed by the vaporization of the other portion.

245. Thilorier's process, as improved by Mitchell and others, will be hereafter illustrated and explained.

246. By analogous means various substances, naturally gaseous, have been liquefied by Faraday, as will be mentioned in treating of those substances.

247. All the cases of liquefaction alluded to, are referable to the law that the power of any matter to pass to the ætiform state is, *ceteris paribus*, less in proportion as the pressure is greater.

*Of the Screw Rod and Plate Frame, employed in the preceding and many other Experiments.*

248. The means by which the glass receiver, employed in the preceding experiment, is upheld and rendered air-tight by the rods, R R, the wooden block, W, the bar, B, and circular plate or disk, D, is one to which I shall resort frequently in the course of my experiments. Hence, to avoid unnecessary recurrence to analogous description, I shall in future designate as a *screw rod and plate frame*, that portion of the apparatus above described, which consists of the *block, bar, plate, and screw rods*.\*

249. The glass in this case is made quite true by grinding on a large lap wheel, such as is employed by lapidaries. The same object is effected in the case of brass plates without grinding, by turning them in a lathe with a slide rest, and by a tool with a fine pyramidal point.

OF CAPACITIES FOR HEAT, OR SPECIFIC HEAT.

250. The power of equal weights of different substances, at the same temperature, in cooling or warming a liquid at a temperature different from their own, will be found very unequal. Thus the effect of a given weight of water being 1000, the effect of the like weight of glass will be 137, of copper 94, tin 51, lead 29, iron 110, gold 29, platinum 31, zinc 92, silver 55. If equal weights of water and mercury, at different temperatures, be mixed, the effect on the water will be no greater than if, instead of the mercury,  $\frac{1}{137}$ th of its weight of water, at the same temperature as the mercury, had been added; and it takes twice as much mercury by measure as of water heated to the same point to have the same influence.

251. The term specific heat is usually employed to designate the quantity of *caloric* in a body in proportion to its *weight* or *bulk*, as specific gravity is used to convey an idea of *weight* compared with *bulk*.

252. In the process above described, the specific heats of substances are found in order to estimate their capacities; the one being necessarily as the other, and the same series of numbers expressive of either.

\* Modification of the screw rod and plate frame are represented in the engraving referred to page 28. (153.)

*Apparatus for illustrating Capacities for Heat.*

253. Let the vessels A, B, and C, be filled with water, and connected by a vertical channel through the wooden block. The water will rise in all. Of course the resistance made by the surface of this liquid will be the same, and the column of water in the tube, T, will be the same. It is the index of the quantity of caloric received by the vessels, and it is an impression that they had all received the same quantity. It is obvious that the quantities received by the vessels are different, as the horizontal areas are different. Of course the water within the vessels is at a different level, and the water in the tube, T, is at a different level, as any evidence of an equilibrium is destroyed by them.

254. In like manner the height of the mercury in the thermometer shows the resistance which substances, whose temperature it measures, are making against any further accession of caloric; but it does not indicate the quantities, of caloric received by them, in attaining the temperature in question. It varies, in them, in proportion to their attraction for this self-repellent caloric; as the quantities of water received by the vessels, A, B, C, are varied in the ratio of their respective areas.

255. *Rationale.*—It may be conjectured that this diversity in the power of substances, equally hot or cold, in influencing temperature, is due to a difference in their capacity to attract caloric, in consequence of which it probably forms denser atmospheres about the atoms of some substances, than it does about those of others.

256. An analogy has already been suggested to exist between the manner in which these calorific atmospheres surround atoms, and that in which earth is surrounded by the air; and also the mode has been suggested in which changes of temperature in the external medium would operate upon the density of such atmospheres. Supposing these preliminary suggestions correct, it would follow that the quantity of caloric absorbed or given out at each exterior change of temperature, by any one congeries of atoms, would be to that absorbed or given out by any other congeries, as the previous condensation of caloric in the one, is to its previous condensation in the other. (173, 174, 175, 176.)\*

\* And the doctrine of Petit and Dulong that the capacities of all elementary substances for heat are the same, will be deferred till I have treated of atomic proportions.

*Of the Specific Heat of Gaseous Bodies.*

257. It was suggested by Lambert and Pictet, and the suggestion was afterwards sanctioned by Dalton, that space may have a capacity for caloric. Consistently with this idea the quantity of caloric in a given space should always be the same whatever may be the gaseous fluid occupied by it. This is consistent with the fact that all the gases have the same capacity for heat, and all undergo a like expansion, in consequence of a like increase of temperature. Agreeably to this view of the case, the cold produced by rarefaction, as in the experiment with the exhausted receiver (212) or the palm glass, (215,) the heat consequent to the compression of air (219) arises from the caloric in the air or vapour, being too little for the space allotted to the air in one case, and too great for that allotted in the other. This idea seems to have been abandoned in consequence of an experiment performed by Gay Lussac. This eminent chemist having made a Torricellian vacuum within a tall cylindrical glass receiver, about 3 inches in diameter and 39 in height, found that when the mercury employed was made to rise or sink in the vacant space so as alternately to enlarge or diminish it, no consequent variation of the temperature took place, since a delicate air thermometer, of which the bulb was included, indicated no change. It appeared, nevertheless, that when a minute quantity of air was admitted, any increase or diminution of the void space, consequent to the rise or fall of the mercury, was as productive, as the same thermometer showed, of a corresponding increase, or diminution, of sensible heat. Hence it has been inferred that a perfectly void space has no capacity for heat, the changes of temperature, consequent to the rarefaction or condensation of æriform fluids, being altogether caused by corresponding changes in the capacity of those fluids for caloric. But as a perfect vacuum must liberate heat with perfect facility, it appears to me that the caloric should be absorbed by the mercury as rapidly as this metal could be made to encroach upon the space occupied by the calorific particles, and that, consequently, no palpable condensation of them could be effected by the above described process resorted to by Gay Lussac.

258. Admitting that, for equal weights, the specific heat of air is seven times as great as that of mercury, that of space being the same by the premises, there could not have been a capacity greater than that of about 200 grains of the metal, whereas a very small stratum of this metal, equal to one-fourth of an inch, would, in the apparatus employed, amount to more than a pound.

259. The following experiments appear to me to be irreconcilable with the idea that the heat acquired by air entering a space does not arise from the specific heat of the space. When a receiver was exhausted so as to reduce the interior pressure to one-fourth of that of the atmosphere, and one-fourth was suddenly admitted, so as to lower the mercurial column in a gauge from about  $22\frac{1}{2}$  inches to 15 inches, heat was produced; and however the ratio of the entering air to the residual portion was varied, still there was a similar result.

260. When the cavity of the receiver was supplied with the vapour of ether, or with that of water, so as to form, according to the Daltonian hypothesis, a vacuum for the admitted air, still heat was produced by the latter, however small might be the quantity, or rapid the readmission. When the receiver was exhausted, until the tension was less than that of aqueous vapour at the existing temperature, so as to cause the water to boil, as in the Cryophorus, or Leslie's experiment, still the entrance of  $\frac{1}{1000}$  of the quantity requisite to fill the receiver caused the thermometer to rise a tenth



of a degree. An of of the cock, through one-fourth of a side, within one-third of a or time, was adequate to produce the change last mentioned.

251. The fact, that heat is produced, when to air, rarefied to one-fourth of its atmospheric density, another fourth is added, seems to me to be irreconcilable with the idea, that this result arises from the compression of the portion of air previously occupying the cavity, since the entering air must be as much expanded as the residual portion is condensed.

252. As, agreeably to Dalton, a cavity occupied by a vapour acts as a vacuum to any air which may be introduced, I infer that when a receiver, after being supplied with ether or water, is exhausted so as to remove all the air, and leave nothing besides aqueous or ethereal vapour, the heat, acquired by air admitted, cannot be ascribed, consistently, to the condensation of the vapour.

253. It was ascertained by De and Marcet, that when the bulb of a thermometer is subjected to a of air while entering an exhausted receiver, that the instrument at refrigeration takes place. But if it be allowed to continue, a or perature ensues. Hence it was inferred by them, that in the final refrigeration, and a consequent absorption of caloric; or an evolution of this principle, in consequence of the expansion of air, which at the first moment of its influx, had been. It appears to me, nevertheless, that in my experiments above upon the thermometer the rapid, and the quantity of air too minute, to allow it to be refrigerated by rarefaction in, and yet afterwards to be so much condensed as to become by the evolution of caloric.

#### OF THE SLOW COMMUNICATION OF HEAT, COMPRISING THE CONDUCTING PROCESS AND CIRCULATION.

##### *Of the Conducting Process in Solids.*

264. It is well known that if one end of a piece of metallic wire, as a common pin for instance, be held in a candle flame, the other end soon becomes too hot for the fingers. It is also known that the heated irons, used in soldering and other processes in the arts, have usually wooden handles, which do not become unpleasantly warm, when the irons within them are hot enough to blister the hands. This inferior power of wood in conducting heat is also well exemplified by the handles of silver tea-pots, which are sometimes altogether of wood; in other instances principally of metal, small portions of wood intervening. In either case, the facility with which the heat is propagated in the comparatively thin metallic socket, is strongly contrasted with the difficulty which it experiences in penetrating the wood.

265. An inferiority of conducting power, when compared with metals, is also displayed by common bone, whistone, ivory, porcelain, and especially glass.



Tin, . . . . .	303.9
Lead, . . . . .	179.6

*Explanation of the Process by which Heat is supposed to be communicated in Solids.*

272. I conceive that in solids, the stratum of atoms forming the surface first exposed to the heat, combining with an excess of this principle, divides it with the next stratum. The caloric received by the second stratum, is in the next place divided between the second and third stratum. In the mean time the first stratum has received an additional supply of caloric, which passes to the second and third stratum as in the first instance; while the quantity, at first received by them, is penetrating further into the mass.

273. It is I trust easy to conceive that, by the process thus suggested, caloric may find its way throughout any body, for the particles of which it may have sufficient affinity. Probably the superior conducting power of metals is due in great measure to a proportionably energetic affinity for caloric.

274. The conjectures, which I ventured to advance respecting the mode in which caloric may exist in atmospheres about atoms, seem to be peculiarly applicable to the case of metals, on account of their great expansibility by heat, and susceptibility of contraction by cold. (174.)

275. If caloric be not interposed in a dense repulsive atmosphere between metallic atoms, how can its removal cause that approximation of those atoms towards each other, without which the diminution of bulk invariably consequent to refrigeration could not ensue?

*Liquids almost destitute of Conducting Power.*

276. That liquids are almost devoid of power to conduct heat, is proved by the inflammation of ether over the bulb of an air thermometer, protected only by a thin stratum of water.

277. The inflammation of ether upon the surface of water, as represented in this figure, does not cause any movement in the liquid included in the bore of the air thermometer at L, although the bulb is within a quarter of an inch of the flame. Yet the thermometer may be so sensitive, that touching the bulb, while under water, with the fingers, may cause a very perceptible indication of increased temperature. By placing the sliding index, I, directly opposite the end of the column of liquid in the stem of the thermometer, before the ether is inflamed, it may be accurately discovered whether the heat of the flame causes any movement in it.



*Communication of Caloric by Circulation.*

278. That caloric cannot be communicated in liquids, unless it be so applied as to cause a circulation of the particles, is demonstrated by the following experiment.

279. A glass jar, about 30 inches in height, is supplied with as much water as will rise in it within a few inches of the brim. By means of a tube descending to the bottom, a small quantity of blue colouring matter is introduced below the colourless water so as to form a stratum as represented at A, in the engraving. A stratum, differently coloured, is formed in the upper part of the vessel, as represented at B. A tin cap, supporting a hollow tin cylinder, closed at bottom, and about an inch less in diameter than the jar, is next placed as it is seen in the engraving, so that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water.



280. The apparatus being thus prepared, if an iron heater, H, while red-hot, be placed within the tin cylinder, the coloured water, about it, soon boils; yet neither of the coloured strata intermingles with the intermediate colourless mass; and on sliding the finger upwards, while in contact with the glass, the heat will be found to have penetrated only a very small distance below the tin cylinder. But if the ring, R, be placed, while red-hot, upon the iron stand which surrounds the jar at S S, the portion of the liquid coloured blue, being opposite to the ring, will rise until it encounters the warmer, and of course lighter, particles, which have been in contact with the tin cylinder. Here its progress upwards is arrested; and, in consequence of the diversity of the colours, a well defined line of separation becomes conspicuous.

281. The phenomena of this interesting experiment may be thus explained.

282. If the upper portion of a vessel, containing a fluid, be heated exclusively, the neighbouring particles of the fluid being rendered lighter by expan-



sion, are more indisposed, than before, to descend from their position. But if the particles, forming the inferior strata of the fluid in the same vessel, be rendered warmer than those above them, their consequent expansion and

motion of speci  
 a, which not being as warm, are  
 principally to the lower part of  
 rise of temperature in a cont  
 B. This statement is equally  
 2, excepting that in the case of  
 on their elasticity may some  
 the influence of temperature

to give place to particles above  
 ier. Hence heat must be ap-  
 in order to occasion a uni-  
 w er l be aëriiform or  
 iform influence of pres-  
 co-o and at others op-

**Experimental Illustration of the Process by which Caloric is distributed in a Liquid until it boils.**



284. On the first application of heat to the bottom of a vessel containing cold water, the particles in contact with the bottom are heated and expanded, and consequently become lighter than those above them. They rise therefore, giving an opportunity to other particles to be heated and to rise in their turn. The particles which were first heated, are soon comparatively colder than those by which they were displaced, and, descending to their primitive situation, are again made to rise by additional heat and enlargement of their bulk. Thus the temperatures reversing the situations, and the situations the temperatures, an incessant circulation is maintained, so long as any one portion of the liquid is cooler than another, or in other words, till ebul-

l takes place; previously to which every particle must have combined as much caloric as it can receive, without being converted into steam.

285. The manner in which caloric is distributed throughout liquids by convection, as above described, is illustrated advantageously by an experiment contrived by Rumford, who first gave to the process the attention it deserves.

286. Into a glass nearly full of water, as represented by the foregoing, small pieces of amber are introduced, which are in specific gravity nearly equal to water, as to be little influenced by gravitation.\* The smooth part of the vessel being subjected to heat while thus prepared, pieces of amber are seen rising vertically in its axis, and after they reach the surface of the liquid, moving towards the sides, where the vessel is heated from the influence of the external air. Having reached the sides of the vessel, they sink to the bottom, whence they are again made to rise. While one set of the pieces of amber are at the bottom of the vessel, some are at the top, and others at intermediate situations; thus de-

\*As amber is rather heavier than water, it is expedient to add some sulphate of soda to increase the specific gravity of the liquid.

monstrating the movements by which an equalization of temperature is accomplished in liquids.

287. When the boiling point is almost attained, the particles being nearly of the same temperature, the circulation is retarded. Under these circumstances, the portions of liquid which are in contact with the heated surface of the boiler are converted into steam, before they can be succeeded by others; but the steam thus produced cannot rise far before it is condensed. Hence the vibration and singing sound which is at this time observed.

288. According to an observation of Gay-Lussac, water boils in metallic vessels at a temperature nearly *two and a half* degrees lower than in those of earthenware.

#### QUICK COMMUNICATION OF HEAT, OR RADIATION.

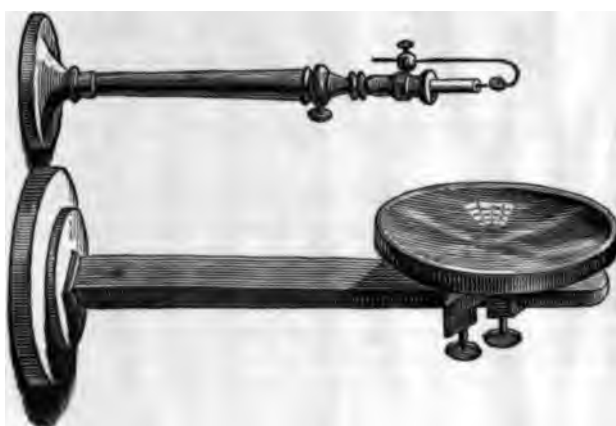
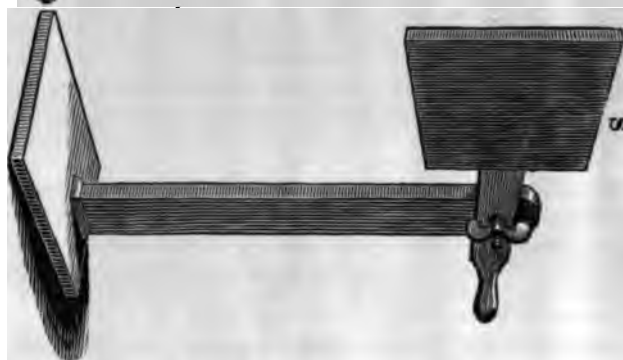
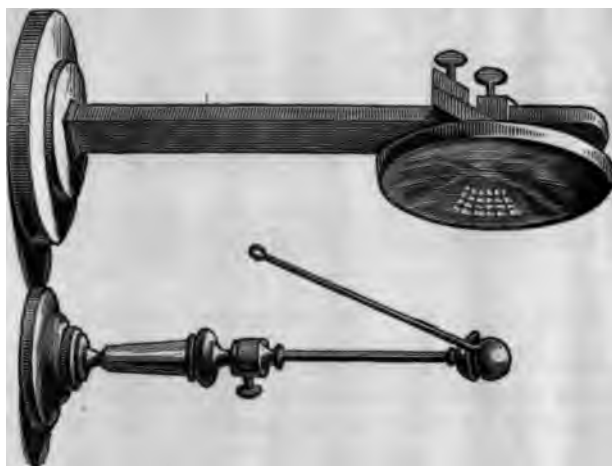
289. It must be evident that the heat which we receive from a fire in opposition to the draught, reaches us neither by the conducting process nor by circulation. Actual contact is evidently indispensable to the passage of heat in either of these modes. The aëriform matter which is in contact with the embers, or the blaze of a fire, forms part of a current which tends rapidly towards the flue, as must be evident from the celerity with which the sparks which accompany it are propelled. The rapidity with which the aërial particles, heated by the fire, are thus carried up the chimney, far exceeds that with which caloric can be communicated, in the opposite direction, either by the conducting process or by circulation.

290. The caloric received from a fire under the circumstances above mentioned, and which is analogous to that by means of which the culinary operations of toasting and roasting are accomplished, is called radiant caloric, or more usually, radiant heat. It has been called radiant, because it appears to emanate in radii or rays from every hot or even warm body, as light emanates from luminous bodies.

291. Radiant heat resembles light also in its susceptibility of being reflected by bright metallic surfaces; in which case it obeys the same laws as light, and is of course liable, in like manner, to be collected into a focus by concave mirrors.

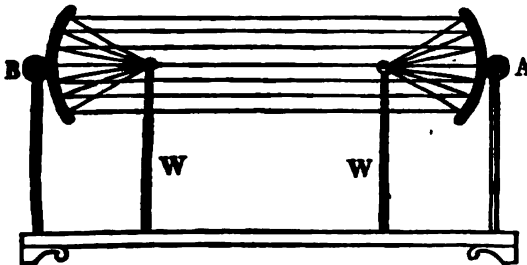


***Phosphorus ignited by Radiant Heat.***





*Model for illustrating the Operation of Concave Mirrors.*



232. The object of the model represented by this diagram, is to explain the manner in which two mirrors operate in collecting the rays of radiant heat emitted from one focus, and in concentrating them in another.

233. The caloric emitted by a body, would pass off in radii or rays, and they pass enlarges; or, in other words, as the squares of the distance. But those rays which are emitted in directions parallel to its axis of symmetry, they may be received, without mechanical imperfections, by another mirror, which should be so placed that the axis of the two mirrors may be coincident; or, in other words, so that a line drawn through their centres, from A to B, may at the same time pass through their foci, represented by the little balls supported by the wires, W W.

234. The second mirror, B, reflects to its focus the rays which reach it from the first; for it is the property of a mirror, duly concave, to render parallel the divergent rays received from its focus, and to cause the parallel rays which it intercepts to become convergent, so as to meet in its focus.

235. The strings in the model are intended to represent the paths in which the rays move, whether divergent, parallel, or convergent.

*Phosphorus ignited at the distance of sixty feet by an incandescent Iron Ball.*

236. The opposite engraving represents the mirrors which I employ in the ignition of phosphorus and lighting a candle by an incandescent iron ball. I have produced this result at sixty feet, and it might be always effected at that distance, were it not for the difficulty of adjusting the foci with sufficient accuracy and expedition. I once ascertained that a mercurial thermometer, when at the distance last mentioned, rose to 110 degrees of Fahrenheit.

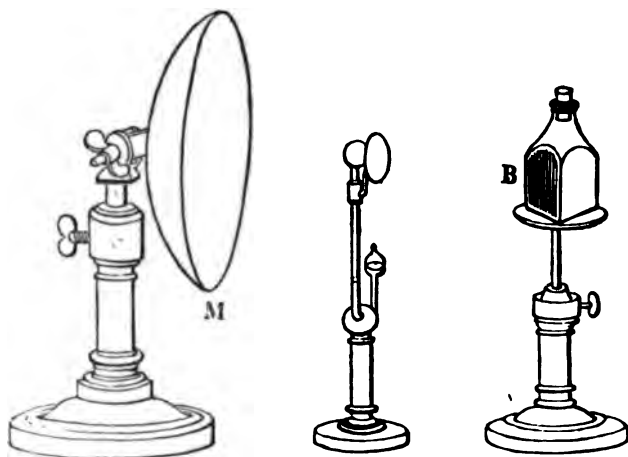
237. A tallow candle is so situated, that its wick, previously imbued with phosphorus, may be in the focus of one of the mirrors. A lamp being similarly situated with respect to the other mirror, it will be easy, by removing the focal image of the flame on any small screen, so to alter the arrangement, as to cause this image to fall upon the phosphorus. This being effected, the screen, S, placed between the mirrors, is lowered so as

\* The axis of a mirror is in a line drawn from its centre through its true focus.

to intercept the rays. The iron ball being rendered white-hot is now substituted for the lamp, and the screen being lifted, the phosphorus takes fire and the candle is lighted.

*Of the Diversity of Radiating Power in Metals, Wood, Charcoal, Glass, Pottery, &c.*

*Diversity of Radiating Power experimentally illustrated.*



298. At M, (see figure,) a parabolic mirror is represented. At B is a square glass bottle, one side of which is covered with tin foil, and another so smoked by means of a lamp as to be covered with carbon. Between the bottle and mirror, and in the focus of the latter, there is a bulb of a differential thermometer, protected from receiving any rays directly from the bottle by a small metallic disk. The bottle being filled with boiling water, it will be found that the temperature in the focus, as indicated by the thermometer, is greatest when the blackened surface is opposite to the mirror, and least when the tin foil is so situated; the effect of the naked glass being greater than the one, and less than the other.

299. *The worst radiators are the best reflectors, and the best radiators are the worst reflectors; since the arrangement of particles which is favourable for radiation is unfavourable for reflection, and vice versa.*

300. A polished brass andiron does not become hot when exposed from morning till night to a fire, so near that the hand placed on it is scorched intolerably in a few seconds. Fire places should be constructed of a form and materials to favour radiation: flues, of materials to favour the conducting process. To preserve heat in air or to refrigerate in water, vessels should be made of bright metal. In the latter case, the brightness is beneficial, only because the surface cannot be bright without being clean. If soiled, its communication with the liquid would be impeded.

301. *Rationale.*—Metals appear to consist of particles so united with each other, or with caloric, as to leave no pores through which radiant caloric can be projected. Hence the only portion of any metallic mass which can yield up its rays by radiation is the external stratum.

392. On the other hand, from its porosity, and probably also from its not retaining caloric within its pores tenaciously as an ingredient in its composition, it opposes but little obstruction to the passage of that subtle principle when in the radiant form; and hence its particles may all be immediately engaged in radiating any excess of this principle with which it is infinitely may have caused them to be transiently united, or in radiating the rays emitted by any heated body, to the emanations from which they have been exposed. We may account in like manner for the penetrating power of earthenware and wood.

393. For the same reason that calorific rays cannot be projected from the surface of a metal, they cannot enter it when projected against it from without. On the contrary, they are repelled with such force as to be reflected without any perceptible diminution of velocity. Hence the superior efficacy of metallic reflectors.

394. It would seem as if the calorific particles which are condensed beneath the surface of the metal, repel any other particles of their own nature which approximate towards the metallic superficies, before actual contact ensues; otherwise, on account of mechanical imperfection, easily discernible with the aid of a microscope, mirrors could not be as efficacious as they are in concentrating radiant heat. Their influence, in this respect, seems to result from the excellence of their general contour, and is not probably impaired by numberless minute imperfections.

### *Radiation of Cold.*

395. A thermometer placed in the focus of a mirror indicates a decline of temperature, in consequence of a mass of ice or snow being placed before it in the situation occupied by the bottle in the preceding figure. This change of temperature has been considered as demonstrating the radiation, and consequently the materiality of cold. For since the transfer of heat by radiation has been adduced as a proof of the existence of a material cause of heat, it is alleged that the transmission of cold by the same process ought to be admitted as equally good evidence of a material cause of cold.

396. The following is the explanation which I give of this phenomenon, agreeing with the opinion that cold is diminished heat.

397. I suppose that caloric exists throughout the sublunary creation, as an atmosphere held to the earth by the general attraction of all the matter in it, being a part combined with bodies in proportion to their affinities or capacities for it, and partly free. The particles of the free caloric I suppose necessarily to exert a self-repellent power, which increases with its density, as in the case of æriform fluids. The repulsive power of caloric being in the ratio of the quantity, it follows that either a diminution or increase of temperature in any spot must equally produce a movement in the caloric particles: in the one case from the spot which sustains the change, in the other towards it.

398. Supposing the surface of a mirror to be subjected to the influence of a ray in which a diminution of temperature has been produced, the rows of caloric particles between the mirror and the space will move into the spot. The removal of one set of the calorific particles from the surface of the mirror, must make room for another set to flow into the situations thus vacated. The curvature of the surface of the mirror renders it more easy for these particles to succeed which lie in the direction of the focus.

*Of the Observations and Apparatus of Melloni.*

309. By means of a thermo-electric pile, and a galvanoscope or multiplier, of extreme delicacy, Melloni has lately ascertained some interesting properties of heat-producing rays, which serve to show a marked difference, and, at the same time, a great analogy between them and the rays of light.

310. Let there be provided three transparent plates, severally of alum, rock salt, and rock crystal or glass, each about an eighth or tenth of an inch thick; it will be found that the effect of the transmitted rays upon the pile, when unimpeded, being 30, that which takes place during the interposition of the rock salt, will be 28, during the interposition of the rock crystal 15 or 16; while during the interposition of the alum the effect will only be two or three.

311. The effect of interposing a plate of smoky rock crystal, will, under the same circumstances, be equal to 14 or 15.

312. In other words, out of 30 parts, rock salt intercepts two parts of the influence of the radiant heat; rock crystal, whether smoky or clear, intercepts about half; while alum, or glass, intercepts nearly the whole.

313. If, in like manner, two pairs of plates be employed, one pair formed of a pane of green glass (impermeable to red rays,) and a plate of alum, the other pair formed of a pane of perfectly opaque black glass, coupled with a plate of rock salt, it will be found that the first mentioned pair intercepts the calorific radiation entirely, while the other permits nearly one third as much to pass, as when not interposed.

314. Hence it appears, that bodies, quite permeable by light, may entirely intercept radiant heat, while others, impermeable by light, allow the passage of radiant heat. Melloni designates the former as *athermane*, the latter as *diathermane* bodies.

315. It follows that permeability to heat-producing rays is not to be confounded with transparency.

316. Radiant heat has been found by Melloni to vary in its power of permeating bodies, according to the source from which it proceeds, and the media through which it may have passed. After passing through nitric acid, more will pass through alum than if received directly from the source.

317. Moreover certain media have, with respect to calorific rays, an influence analogous to that which coloured media have with respect to light, in allowing some rays to pass, while others are arrested.

318. This property of the diathermane bodies, is called diathermansie. Rock salt seems to be a diathermane body, devoid of diathermansie. The last mentioned property lessens as the body is thinner, and may, as in the case of coloured media, be rendered null by an extreme tenuity.

319. The non-luminous calorific rays have been ascertained by Melloni to be susceptible of refractions analogous to those of light. When the thermo-electric pile is so situated as that the rays of heat cannot directly reach it, by interposing a prism of rock salt, having a refracting angle of  $60^\circ$ , the rays will be made to reach the pile.

320. From experiments performed by Prof. Forbes, of Edinburgh, with the aid of Melloni's thermoscope, above alluded to, it appears that radiant heat, unaccompanied by light-producing rays, is susceptible of polarization. Respecting this fact, some further mention will be made in treating of the polarization of light.

MEANS OF PRODUCING HEAT, OR RENDERING CALORIC  
SENSIBLE.

*Of the Solar Rays as a Source of Heat.*

321. Of all the natural sources of heat, the sun is obviously the most prolific.

322. The solar rays may be collected into a focus either by the refracting influence of glasses or the reflecting power of mirrors. They may be converged by reflection, in a mode analogous to that illustrated in the case of radiant heat.

323. The glasses employed for concentrating light are called lenses from their shape, which is that of a double convex lens.

324. As the intensity of the heat produced by the solar beams is in proportion to the quantity of them which may be collected upon any given spot, there appears to be no limit to the degree of heat producible by their concentration, excepting that arising from the difficulty of making lenses sufficiently large and free from defect, or of associating mirrors sufficiently numerous and well arranged.

325. Until lately, scarcely any occurrence of antiquity appeared more unaccountable than the destruction of the Roman ships, which Archimedes is alleged to have accomplished, by concentrating upon them the rays of the sun. Nevertheless, of this wonderful feat, Buffon seems to have discovered the means. Having arranged a number of plane mirrors so as to concur in reflecting the solar image upon the same spot, he was enabled to fuse lead at a distance of 140 feet. This contrivance resembles that which Archimedes employed, if we may judge from the accounts which have been given of the latter. Previously to the employment of pure oxygen gas, the hydro-oxygen blow-pipe, and voltaic electricity, there was no known mode of rivaling the heat produced by large burning-glasses and mirrors.

*Sensible Heat evolved by Electricity.*

326. The power of lightning to produce ignition is displayed by the conflagration of ships and barns, in consequence of the ignition of cotton, hay, or other combustibles. The power of the electric spark to ignite an inflam-

mable gaseous mixture is agreeably illustrated, by means of the apparatus described in the following article.

*Application of an Electrophorus to the Ignition of Hydrogen Gas, generated in a Self regulating Reservoir.*

327. In order that the interior of this apparatus may be described, (see fig. below) the side of the box, B, below the reservoir, R, is supposed to be removed. On the bottom of the box is a square metallic dish covered by a stratum of sealing wax. The metallic plate, D, is supported behind by a glass rod, cemented to a socket soldered to a hinge. Upon this hinge, like the lid of a trunk, the plate moves freely while connected with the lever, L, by a silken cord. The lever, L, is attached to the key of the cock, C; so that opening the cock causes the plate to rise, and touch the knob, *n*, of the insulated wire. This wire terminates just before the orifice of the tube, *t*, proceeding from the cock, and about one-eighth of an inch from another wire, supported upon that tube.

328. The glass reservoir, R, receives into its open neck, the tapering part of glass vessel, V, which is so proportioned, and fitted to the neck by grinding, as to make with it an air-tight juncture.

329. Below this juncture, the vessel, V, converges, until it assumes the form of tube, reaching nearly to the bottom of the reservoir. Around the tube thus formed, a coil of zinc is supported, as to be above the orifice of the tube constituted as abovementioned.



330. If the reservoir be sufficiently supplied with diluted sulphuric acid, the reaction between this solvent and the zinc will evolve hydrogen gas. The gas thus evolved, if not allowed to escape, will force the liquid which generates it through the orifice of the tube proceeding from the vessel, V, into the cavity of this vessel, until the quantity of the acid remaining below is insufficient to reach the zinc. When ever this takes place, the evolution of hydrogen ceases. As soon, however, as, by opening the cock, any portion of the gas is allowed to escape, an equivalent bulk of acid descends into the reservoir, and reacts with the zinc until, by the further generation of

hydrogen, the portion of acid which may have descended shall again be expelled from the lower into the upper vessel. At the same moment that, by turning the cock, C, a jet of gas is emitted, the plate of the electrophorus being lifted against the knob, *n*, of the wire, an electrical spark will pass from the other end of this wire to that of the wire supported by the cock, and of course uninsulated by its communication with the operator's hand. Consequently the jet of hydrogen will be ignited, and will light a candle exposed to its influence.

331. For a rationale of the electrophorus, as also for other exemplifications of the igniting power of electric discharges, I refer to my treatise on statical or mechanical electricity.

*Ignition by Galvanism.*

*Galvanic Apparatus for Lighting a Lamp.*

332. The following figure represents an instrument for lighting a lamp by means of a galvanic discharge from a calorimotor; for a more ample explanation of which I must refer the reader to my lectures on galvanism.

333. The plunger, P, being depressed by means of the handle attached to it, some acid contained in the box, B, is displaced, so as to rise among the galvanic plate. By the consequent evolution of the galvanic fluid, a platinum wire, fastened between the brass rods forming the poles of the calorimotor, and projecting over the lamp, seen at R, is rendered white hot, and a filament of the wick, previously laid upon it is inflamed.

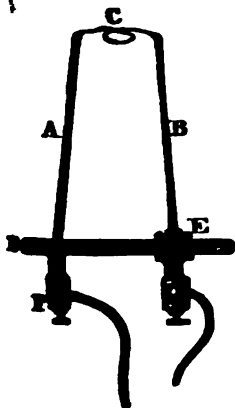


22. The weight acts as a counterpoise to the plunger, and when it is not depressed by the hand, keeps it out of the acid.

#### *Galvano-ignition Apparatus.*

335. In many of my experiments, for the purpose of producing the temperature of combustion in cavities inaccessible by ordinary means, I employ a wire ignited by being made a part of a galvanic circuit.

336. Of the apparatus by which this object is effected, I shall here give a description accompanied by a figure, which will convey a general idea of the contrivance, applicable to all cases where it may be used. Having thus prepared the student, I shall in future refer to it under the name at the head of this article, in order to avoid circumlocution, and unnecessary recurrence to analogous description. D represents a section of a metallic disk. A B, two metallic rods, which should be of iron, if in contact with mercury, but which otherwise may be of brass, are made to enter the cavity. If, as in general, the rods pass through a metallic plate or cylinder, one of them may be soldered to the plate or cylinder. The other must be so secured, where it passes through the metal, by a collar of leather, E, as to insulate it from all metallic contact, and to render the aperture through which it enters, air-tight if necessary. The rods may extend into



the cavity to any convenient distance, their terminations being approximated, more than, as may be desirable, but not brought in contact. To one of these rods, it terminates within the cavity, one end of a fine platinum wire is soldered; the other end of the wire being soldered in like manner to the similarly situated termination of the other rod. To the rod secured by the collar of leather, at the termination on the outside of the cavity, a gallows screw is attached, by means of which a handle or copper rod may be made fast at one end, while the other is fastened to the poles of a competent calorimotor. To the other pole of the calorimotor, another rod is attached at one end, which at the other may be secured by a galvanometer, either soldered to the plate, or to the projecting extremity of the uninsulated rod, as in the figure. Sometimes the last mentioned rod is left at liberty, so as to be made to touch the uninsulated rod. If, under these circumstances, the calorimotor is put in operation, the wire will be ignited.

*Ignition by Collision.*

337. The ignition of spunk, tinder, or gunpowder, by means of flint and steel, comes under this head. In the rotary match box, the collision is produced by a wheel thrown into rapid rotation. An analogous apparatus, called a steel mill, had long been employed to procure light in mines infested with light carburetted hydrogen, prior to Sir H. Davy's invention of the safety lamp. This gas explodes on coming into contact with the flame of a lamp or candle, but is not ignited by the scintillations from a steel mill.

*Heat produced by Percussion.*

338. A rod of iron hammered with great rapidity by a skilful workman, will become so hot as to ignite a sulphur match, and phosphorus may be easily ignited in this way; but the same piece of iron cannot be ignited by percussion more than once.

339. Coins grow hot when struck in the coining press, but, if cooled during each interval between the blows, are less heated at each successive blow. At the same time the density of the mass is permanently increased, probably by the expulsion of the caloric, interposed between the metallic atoms. (272.)

*Heat produced by Friction.*

340. Friction, as a means of producing heat, differs from percussion; since in the case of friction, the effect being confined to the surfaces of bodies, there is no condensation of the mass subjected to the process. Collision differs both from percussion and friction; for it produces ignition only in the minute portions of matter which are struck off. The masses employed are not heated.

341. It is well known that savages avail themselves of the friction of wood to produce fire. Wood revolving in the lathe may be carbonized, throughout the circle of contact, by holding against it another piece properly sharpened. By rubbing one cork against another, sufficient heat is produced to ignite phosphorus.

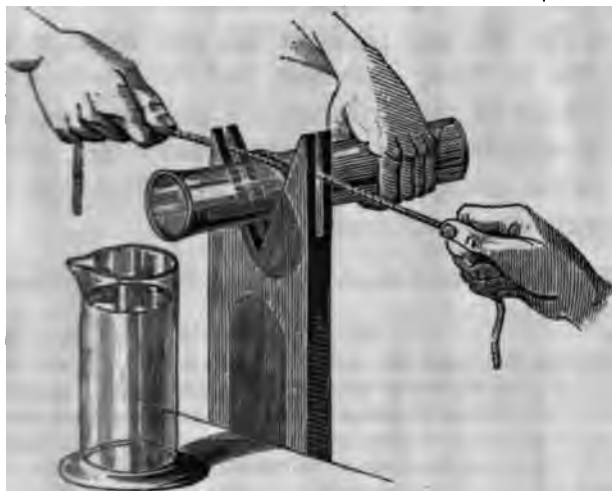
*Glass so heated by the Friction of a Cord, as to separate into two parts on being subjected to Cold Water.*

342. The process for dividing a tube, which I am about to describe, illustrates at once the heat produced by friction, and the non-conducting power of glass.

343. Some years ago, Mr Isaiah Lukens showed me that a small phial or tube might be separated into two parts, if subjected to cold water, after having been heated by the friction of a cord made to circulate about it, by two persons alternately pulling in opposite directions. I was subsequently enabled to employ this process for dividing large vessels of four or five inches in diameter; and likewise to render it in every case more easy and certain, by means of a piece of plank forked like a boot jack, as represented in the following figure, and also having a kerf or slit cut by a saw, parallel to, and nearly equidistant from, the principal surfaces of the plank, and at right angles to the incisions forming the fork.

344. By means of the fork, the glass is easily held steady by the hand of one operator. By means of the kerf, the string, while circulating about the glass, is confined to the part where the separation is desired. As soon as the cord smokes, the glass is plunged into water, or if too large to be easily immersed, the water must be thrown upon it. This method is always preferable when the glass vessel is so open, that on being immersed, the water can reach the inner surface. As plunging is the most effectual method of employing the water, I usually, in the case of a tube, close the end which is to be sunk in the water, so as to restrict the refrigeration to the outside.





**Exposition.**—If the friction be continued long enough, the glass, though a very conductor of heat, becomes heated throughout in the part about which the friction takes place; of course it is there expanded. While in this state, being suddenly cooled by the cold water on the outside only, the stratum of particles immediately affected contracts, while that on the inside, not being chilled, undergoes no slight change. Hence a separation usually follows: see (264, &c.)

### *Ignition by Attrition.*

6. If, whilst a thin disk of sheet iron is made to revolve rapidly upon a lathe, the circumference be brought into contact with a piece of steel, heat will be so copiously evolved at the place of collision, that the steel may be actually divided by the successive ignition and abrasion of a portion of its particles. The ignition is confined to the steel, because the heat, evolved in this case, is too much divided upon the whole surface of the iron, to affect any part materially; whereas, a few disks of steel having to encounter successively many of iron, the heat, raised by the attrition, accumulates in the former, so as to produce ignition.

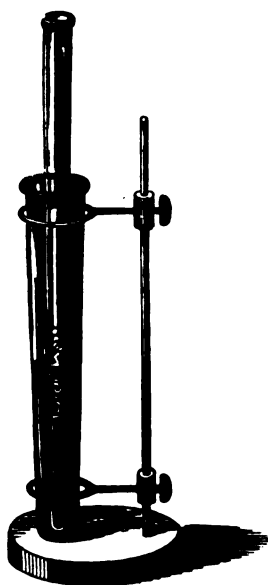
7. This case differs from that of pure collision, since, although heat is evolved in the abraded particles, it is also produced in the mass; and it differs from that of friction, since, although both of the masses are heated, most heat is evolved in the matter which is abraded.

### *Heat produced by Combination.*

1. The union of tin or lead with platinum is productive of a remarkable elevation of temperature. For the exhibition of this phenomenon, both must be in the state of foil, and the more fusible metal rolled up in a scroll, so as to form a scroll as large as can be conveniently ignited in the blowpipe. As soon as the scroll reaches a red heat, it becomes instantaneous and incandescent, the union being effected with an extraordinary energy.

*Experimental Illustration.*

349. Tin foil and platinum foil are rolled up in scroll, the tin being innermost, and the whole subjected to the flame of the hydro-oxygen blowpipe, supplied with currents of hydrogen gas and atmospheric air. Almost as soon as the mass reddens, it becomes incandescent and an energy almost explosive. (250, &c.)

*Boiling Heat produced in Alcohol, by the Mixture of Sulphuric with Water.*

350. The evolution of caloric, produced by the mixture of liquids, has long been an object of attention among chemists. A sensible increase of temperature arises from the mixture and consequent combination of alcohol and water. When sulphuric acid is added to the mixture, an analogous result ensues, but the rise of temperature is much greater. The heat, thus evolved, may be conveniently exhibited by the action of the apparatus represented by the adjacent figure, and the process which I am about to describe.

351. Into the inner tube introduce as much alcohol, coloured to render it more discernible, as will occupy it to the height of three or four inches. Next pour water into the outer tube till it reaches about one-third as high as the liquid contained in the inner tube; and after this add to the water about three times its bulk of concentrated sulphuric acid. The liquid in the inner tube will soon boil violently, so as to form a foam.

*Solution the Means of producing Heat or Cold.*

352. Solution produces either heat or cold, according to the nature of the substance dissolved and of the solvent employed.

353. In absorbing and dissolving gaseous ammonia or chlorohydrogen gas, the resulting liquid becomes hot. Water becomes cold in dissolving nitre, and still colder in dissolving nitrate of ammonia. Sulphuric acid becomes at first boiling hot, and afterwards freezing cold, by successive additions of snow.

*Evolution of Caloric by Mechanical Action inducing Chemical Decomposition.*

354. With the view of showing the necessity of distinguishing between latent cause from sensible heat, the explosion of a fulminating powder by percussion was exhibited. This phenomenon falls under the definition given at the head of this article. Ignition produced in this way has been advantageously applied to fire-arms and fowling pieces. (30.)

355. It seems probable that the mechanical force of the blow causes the particles of the compound to be nearer to each other; in consequence of such an arrangement of the elements ensues, inconsistent with the retention of the large quantity of caloric with which they were previously combined.

356. The inflammation of a friction match, appears to me to arise in part from heat generated by friction, and in part from mechanical impulse, inducing a chemical reaction between the ingredients, and exposing them to the air. Matches, which take fire when crushed, owe this result to the last and not cause only.

357. The rationale of the chemical reaction of the ingredients, will be given under the heads of sulphur, phosphorus, and the chlorates.

### *Heat produced by Condensation experimentally illustrated.*

358. Spunk or tinder may be ignited, if introduced into a condenser of appropriate construction, and the air forcibly condensed upon it.

359. It has already been shown that, during its rarefaction, air becomes cooler, while during its condensation it becomes warmer. It seems that when the compression is carried very far, so much caloric is liberated as to cause ignition. This result is attained by means of a small condenser, the construction of which does not differ from that which has been described (145. &c.), excepting that a cock for the introduction of the spunk is substituted for the valves. The ignition is accomplished by having the piston so situated, as that there may be as much air as possible included by it, and then driving it home, with a jerk, so as to condense the air upon the matter to be ignited with great force and rapidity. Sometimes the instrument is made of glass without a cock, so that the ignition may be seen; the spunk being inserted into a cavity in the end of the piston, which must of course be withdrawn as soon as the ignition is effected, in order to make any useful application of the ignited spunk.

360. It appears evidently from this phenomenon that, in air, the quantity of caloric is proportion to the ponderable matter lessens as the density increases. Or, in other words, as the space allotted to the air is diminished.

361. This inference would appear, at first view, irreconcilable with those experiments which demonstrate that, in steam, the quantity of caloric is nearly equal to the weight of water; but the discordancy disappears when we consider that the heat of the condensed air is estimated after the manner of the sensible heat liberated by the compression; while in the case of steam this cannot be permitted, as a loss of sensible heat would be attended with a partial condensation, producing a proportionate diminution of density.

362. If steam, formed at the boiling point of  $212^{\circ}$ , and having no access to water in the liquid form, were to be raised to some higher temperature, and then condensed, it might be subjected to compression without being partially liquefied; so that the same law would apply to it as to atmospheric air, which always exists at a heat far above its boiling point, and has no access to any of its own kind of ponderable matter in the liquid form.

363. By the boiling point of air, I mean that temperature below which it would become liquid. We have, I think, reason to infer that all æriform fluids would prove susceptible of liquefaction, if our ability to condense them, or our power of producing cold were unlimited.

364. It has been suggested (257, &c.), that the caloric thus condensed may belong to the space, and not to the air.

### *Experimental Illustration.*

365. Spunk ignited in consequence of the compression of air, by means of an appropriate condenser.

### *Of Fermentation as a Source of Heat.*

366. It is well known that vegetable substances, while undergoing fermentation, acquire a great accession of heat; and that green hay is at times spontaneously ignited. The heat generated in stable litter is employed to sustain the temperature necessary to the corrosion of the metal in the manufacture of white lead.

### *Of Vitality as a Source of Heat.*

367. The temperature of warm blooded animals demonstrates the power of animal life to evolve caloric. In no other respect is chemical reaction so analogous to that which takes place within the domain of vitality, as in their common association with heat, both as cause and effect. The old chemical law that bodies do not act unless fluid, to which the actual exceptions are but few, shows how much the processes of chemistry are dependent on the principle, without which there could be no fluidity. The dependency of life on temperature is self-evident. Seeds and eggs lie dormant until excited by a due degree of heat.

### *Of the Means of exciting or supporting Heat for the Purposes of Chemistry.*

368. It is well known that the activity of fire is dependent on the supply of air, as well as on the quantity and quality of the fuel.

369. As the air which comes into contact with a fire is necessarily much rarefied by the expansive power of heat, it has consequently a tendency to ascend in a vertical current, giving place to the colder and heavier air in the vicinity, agreeably to the principles already illustrated. See (282) and (286). The limits of this vertical current of heated air, in the case of a smoky lamp flame, are well indicated by the fuliginous particles. It may, however, be observed that the influx of the cold air takes place not only at a level with the flame, where it must quicken the combustion, but also above the flame, where it narrows the heated column and retards its progress. In the Argand lamp, a glass chimney defends the vertical current from lateral pressure, until it has attained a sufficient height to cause an adequate current of air to act upon the flame.

370. In conformity with the principle thus illustrated by this elegant and useful contrivance, all air furnaces are constructed. The hot air and vapour proceeding from the fire, being received into a flue, or the furnace being tall enough of itself to protect the ascending current, all the air which flows in to take its place is made to pass through the fuel.

371. It would not be expedient to take up the time of the student with a detailed explanation of the various furnaces used by chemists. Some of them will be introduced in subsequent illustrations, as associated with

processes, in which their utility and the method of using them will be evident.

### *Experimental Illustration.*

372. An Argand lamp shown and explained. Also an Argand lamp with concentric wicks.

### *Of the Bellows, and of Forge Fires.*

373. The bellows is so universally known as the means of exciting combustion employed by smiths, as to render it scarcely necessary to mention the forge fire as among the most efficient and convenient methods of producing heat for the purposes of chemistry. The supply of air is, in this case, yielded by an operation analogous to that of the condenser. (148, &c.)

374. In the double bellows, the additional compartment performs a part, in equalizing the efflux, equivalent to that of the air vessel in the case of the forcing pump, the valves operating in the same way. (143.)

### *Lamp without Flame.*



375. About the wick of a spirit lamp, a fine wire of platinum is coiled, so as to leave a spiral interstice between the spiral formed by the wire; a few turns of which should rise above the wick. If after lighting a lamp thus constructed, the flame be extinguished by a gentle blast, or the transient application of an extinguisher, the wire will be found to remain red hot; as it retains sufficient heat to support the combustion of the alcoholic vapour, although the temperature is inadequate to produce inflammation.

376. *Rationale.*—The metallic coil appears to serve as a reservoir for the caloric, and gives to the combustion a stability, of which it would otherwise be deficient. There is some analogy between the operation of the wire in acting as a reservoir of heat in this chemical process, and that of a fly wheel as a reservoir of momentum in equalizing the motion of machinery.

### *Of the Mouth Blowpipe.*



377. As a fire is quickened by a blast from a bellows, so a flame may be excited by a stream of air propelled through it from the blowpipe. The instrument known by this name, is here represented in one of its best forms. It is susceptible of various other constructions; all that is essential being a pipe of a size at one end suitable to be received into the mouth, and towards the other end having a bend nearly rectangular, beyond which the bore converges to a perforation, rather too small for the admission of a

common pin. There is usually, however, an enlargement, as represent in this figure, to collect the condensed moisture of the breath.

378. The mouth blowpipe is of great service in assaying minute tions of matter, so as to form a general idea of their nature. The brated Berzelius, who has written an octavo volume on the subject of th strument, informs us that by means of it Gahn discovered tin in a min in which it had not been detected by analysis, although existing only i proportion of one per cent: also that he had often seen him extract a bule of metallic copper from the ashes of a quarter of a sheet of p The utility of the mouth blowpipe will be manifested in several future i trations.

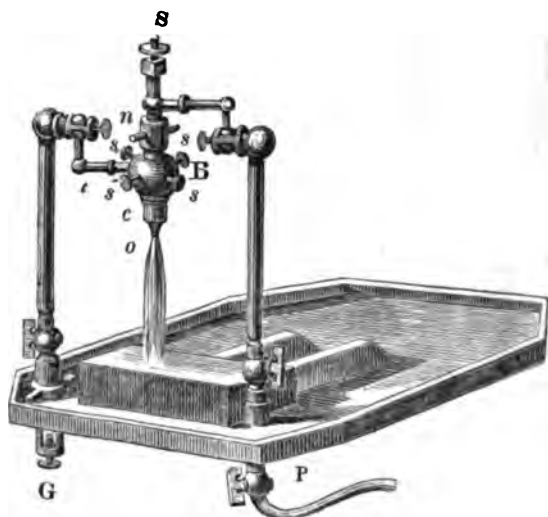
### *Of the Enameller's Lamp.*

379. A lamp, so made as to be excited by a jet of air from a station blowpipe, supplied by a double bellows, gasometer or gas-holder, is emp ed much by chemists and artists for bending glass tubes, or heating the as to blow, on them, bulbs for thermometers. Such lamps having been ginally used by enamellers, are designated accordingly.

### *Of the Hydro-Oxygen or Compound Blowpipe.*

380. In the year 1801, by the invention of the hydro-oxygen or compound | pipe, of which I published an account the following year, I was enabled to fus veral of the pure earths which had previously been deemed infusible; and like not only to fuse, but to volatilize pure platinum. Subsequently, my friend Prof Silliman, by a more extended use of the instrument, fused a great number of stances insusceptible of fusion by the common blowpipe. My memoir was n lished in London, in Tilloch's Magazine; also at Paris, in the Annales de Ch and was noticed by Murray in his treatise of chemistry, and by Dr. Hope, in lectures; yet, when a modification of the hydro-oxygen blowpipe was contrive Mr. Brooke, Dr. Clarke, by means of this modification, repeated my experim and those of Professor Silliman, without any other notice of our pretensions such as were calculated to convey erroneous impressions.

### *Engraving and Description of an improved Compound Blowpipe and its Append*



381. The following figure represents a compound blowpipe which I contrived executed myself in the year 1813; but, fearing it might be deemed unneces

I did not then publish an account of it. Experience has shown that the use of its structure does not render it more difficult to use than the instruments intended for the same purpose; while its parts are peculiarly susceptible of advantageous adjustment.

It consists of a brass ball, with a vertical perforation, terminating in a male screw at the top, and a female screw below. Another perforation, at right angles to this, communicates with the tube *t*, which enters the ball at right angles. A smaller brass ball may be observed above, with perforations similar to the larger ball, and a tube, in like manner, entering it laterally. This ball is in a male screw below as well as above. The thread of the lower screw is to the left, while that of the screw of the larger ball, which enters the lower ball, is curved to the right. Hence the same motion causes the male screws to revolve from each other, and thus determines the degree of compression of a cork which is placed between them in the nut. At *S*, above the ball, may be observed, with a milled head. This is connected with a small tube which passes through the cork in the nut, *n*, and reaches nearly to the external flame from which the flame is represented as proceeding. This tube is for the purpose of heat, but at its lower end terminates in a tube of platinum. It communicates with the cavity of the upper ball, but is prevented by a cork from communicating with the cavity in the other ball. Hence it receives heat which may be delivered into the upper ball from the lateral pipe which enters it, but receives none of the gas which may enter the lower ball, B. At the female screw of the latter, a perforated cylinder of brass, *c*, with a long male screw, is fitted. The perforation in this cylinder forms a conical tube in the ball, but narrows below, and ends in a small hollow cylinder *n*, which forms the external orifice of the blowpipe, *e*. The screws, *s s s*, are to keep, in the axis of the larger ball, the tube which reaches it from the cavity of the smaller ball. The intermediate nut, by turning about the tube the cork which surrounds it, prevents any communication between the cavities in the two balls. By the screw, *S*, in the vertex, the orifice of the central tube may be adjusted to a proper distance from the external orifice of the different cylinders, and as many central tubes with platinum orifices of different sizes were provided, so that the flame might be varied in size, agreeably to the view.

I have always deemed it best to transmit the oxygen gas through the tube in which two volumes of the hydrogen being required for one volume of oxygen, a larger tube ought to be used for the former; and the jet of hydrogen is between a jet of oxygen within it, and the atmospheric air without.

Under the table is a gallow, *G*, with a screw for attaching a pipe, leading to a regulating reservoir of hydrogen.

In order to put this apparatus into operation, it is affixed to a table, as represented in the figure, or to a smaller stand, and secured to the side of the hydrostatic cistern, so as to be conveniently situated for receiving the oxygen from a tube, through the pipe, *P*, and the hydrogen through a pipe attached at *G*.

Another pipe, proceeding from a reservoir of hydrogen gas, is attached, by the screw and gallow, *G*, to one of the tubes communicating with the cistern.

The cavity of the hydrostatic blowpipe may be supplied, either with oxygen, or with atmospheric air. In either case, in order to have the instrument in full operation, it is necessary to open the cocks duly, and inflame the hydrogen.

The heat produced, in this way, by the combustion of hydrogen with atmospheric air, is sufficient to fuse platinum; and when oxygen gas is employed, that any other, may be volatilized. The facility with which the hydro-oxygen blowpipe excited by pure oxygen or common air merely, may be made to act, in any direction, renders it peculiarly serviceable in many operations; its simplicity is a great recommendation.

*Account of the Lime Light, and of Daniell's and Maughan's Blowpipe, so called erroneously.*

It has been said in some of the British newspapers, of the application of lime to the light reflected by lime, when subjected to the flame of the blowpipe. This is treated as a new invention, although in my original Memoir, published in the year 1802, I spoke of the light so created as intolerable to the eye.

A similar observation will be found in the description given by my friend William of the phenomenon in question. It follows that the claim can only, say claim to a new application of a previous discovery.

392. In my original memoir on the hydro-oxygen blowpipe, I described and represented by engravings two methods of causing the currents of the two gases employed to meet. Agreeably to one of these, two perforations were made to unite and form on at about the tenth of an inch from the external orifice, so as that a section of the aggregate would resemble in shape the letters XY. Agreeably to the other method, smaller tube was made to enter and to be concentric with a larger one, the latter being a little longer, so as that at a little distance from its end, the orifice of the former terminated. The oxygen being supplied through the inner tube, and the hydrogen through the outer one, the admixture of the oxygen with the hydrogen, took place within the bore of the external tube, at a small distance from its orifice.

393. Not being enabled to procure any platina at the time, I could not construct blowpipe, of the last mentioned kind, sufficiently refractory; but about the year 1815, I constructed the compound blowpipe above described, and exhibited it to Professor Silliman, who mentioned this fact in a letter written within a year afterwards. From the time that I was elected Professor of Chemistry in 1818, I have employed this form of the instrument, of which an engraving and description was given in the Franklin Journal (Vol. I, 1826, p. 195,) of a simpler instrument upon the same principle, an engraving and description of which will be found in Silliman's Journal for 1822. Yet both Professor Daniell and Mr. Maugham, resorted to analogous contrivances. The former has been called Daniell's hydro-oxygen blowpipe, the other also is distinguished by the name of its contriver. It differs from mine essentially only in being recurved into an acute angle, so as to throw the flame on a cylinder lime, for the purpose of illumination. In order to accomplish the same object, I have only to direct mine obliquely upwards, instead of resorting to a direction deviating little from the perpendicular, as is usually preferable. It is surprising that under these circumstances, Maugham should have received a premium for the instrument which he had thus modified, without any reference to the original inventor.

#### *Improved Process for the Fusion of Platinum.*

394. Latterly by multiplying the jets, and using great pressure, I have been enabled to fuse more than two pounds troy, of platinum, into a malleable mass. The method which I employed, was the same essentially as that described in Silliman Journal, as abovementioned. The gases are made to mingle in a common cavity and afterwards to supply jet tubes of about the usual size of those employed in blowpipes; these are to be made more or less numerous, in proportion to the quantity of metal to be fused. The great desideratum is to have the pressure on the gases sufficiently great, and at the same time perfectly steady.

#### MEANS OF PRODUCING COLD, OR RENDERING CALORIC LATENT

##### *Cold by Vaporization.*

395. The cold produced by evaporation has been illustrated by an experiment in which a jet of ether, co-operating with a blast, was productive of the congelation of water. Pure prussic acid will enable me hereafter to exhibit a phenomenon still more surprising; I mean that of the freezing of one portion of a liquid, by the vaporization of another portion. I shall now proceed to show that the freezing of water may be caused by the ebullition of ether.

##### *Water Frozen by Boiling Ether.*

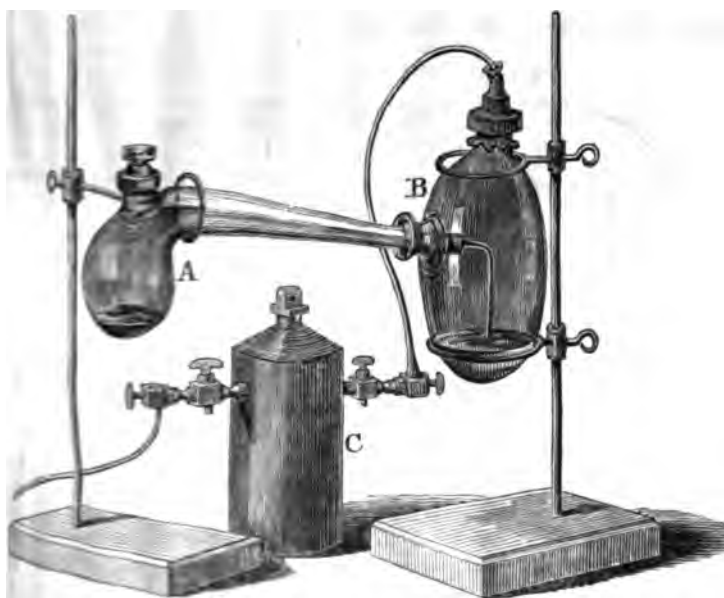
396. Let a portion of water, just adequate to cover the bottom, be introduced into the vessel represented in the following engraving, as suspended within a receiver. Over the water let ether be added, in quantity sufficient to form a stratum from an eighth to a quarter of an inch in depth. If, under these circumstances, the receiver be placed on the air pump plate, and sufficiently exhausted, the water freezes, while the ether boils.





397. *Rationale.*—The freezing of the water in contact with the boiling ether, is in consequence of that increased capacity to combine with caloric already explained. (186.) Under these circumstances, the boiling point of the ether is depressed below the freezing point of water; and consequently it causes the congelation of that liquid from the same cause, that melted tin or lead will congeal under boiling water.

*Engraving and Description of an Apparatus and Process for the rapid Congelation of Water, by the explosive Evolution of Ethereal Vapour consequent to the combined influence of Rarefaction, and the absorbing power of Sulphuric Acid.\**



398. The retort A, contains a small portion of water covered by a stratum of hydric sulphuric ether. The vessel B, holds a stratum of sulphuric acid of about two inches deep, at the deepest part. Into a tubulure on the side of this vessel, the beak of the retort is ground to fit air-tight, and

\* By the liberality of the American Philosophical Society, I am permitted to introduce this article in my Compendium, although communicated to them for a volume of their Transactions now in the press

is made to receive one end of a recurved tube, of which the other ascends about half an inch below the surface of the acid. There is a glass bottle, C, of which the mouth is well closed, and which is furnished with two cocks, one of which communicates with the air pump, the other with the vessel, B. The mode of operating is as follows: the bottle is first exhausted, and kept in a state of exhaustion by closing both of the cocks, the pump being put into operation and the cocks opened simultaneously, the power of the acid to absorb the vapour, co-operating with that of the vacuum and the pump in exhausting the air and vapour from the retort, causes an explosive vaporization of the ether, and a consequent rapid cooling of the water.

*Congelation of Water in an exhausted Receiver by the aid of Sulphuric Acid.*

399. In the experiment above illustrated, water is frozen by the abstraction of caloric, consequent to the copious vaporization of ether unrestrained by atmospheric pressure. In vacuo, water undergoes vaporization, analogous to that of the ether in the preceding experiment; aqueous vapour evolved in this case is so rare, that it cannot act on the air-pump valves with sufficient force, to allow of its being pumped out, a receiver with the rapidity requisite to produce congelation. However



the process which I am about to describe, water is frozen by its own vapour.

400. A thin dish, of glass, covered by a quantity of water, and over some concentrated sulphuric acid in a broad receiver is placed within a receiver on the air-pump plate, as presented in the accompanying engraving. Under these circumstances, the exhaustion of the receiver causes the congelation of the water.

401. *Rationale.*—So long as there is no diminution of the thin vapour which, in the absence of the air, occupies the cavity of the receiver, the elastic reaction of that vapour prevents the production of more; but when, as in the case in point, the vapour is largely in contact with sulphuric acid and consequently rapidly absorbed, a corresponding vaporization of the water takes place to supply the deficiency thus created. The caloric requisite for the generation of the vapour thus formed, is taken from the residual liquid, which finally freezes in consequence. (229.)

*Improved Apparatus for freezing Water by the aid of Sulphuric Acid.*

402. Finding the experiment, for which the apparatus represented in the preceding figure is usually employed, liable to fail from the imperfectness of the cocks, dependent for their efficacy on a metallic joint, I contrived the apparatus which the opposite engraving is intended to represent, and I shall proceed to describe. A brass cover is so well fitted to the receiver

***Apparatus for the Congelation of Water in Vacuo, by means of  
Sulphuric Acid.***





the jar as to be airtight. In operating, the bottom of the jar was covered with sulphuric acid, and another jar with feet, also supplied with acid enough to make a stratum half an inch deep on the bottom, is inserted as represented. The bottom of the vessel last mentioned, is, by the feet, kept at such a height above the surface of the acid in the jar, as not to touch it. Upon the surface of the glass vessel, a small very thin sheet brass is placed, made concave in the middle, so as to hold a small quantity of water. The brass cover is furnished with three cocks, one communicating with the air-pump, another with a barometer, and the third with a funnel supplied with water.

With the apparatus thus arranged, having made a vacuum on a day, I was enabled to freeze water situated on the plate, and to keep the congelation till the Thursday following. As water in the state of vaporates probably as fast as when liquid, the whole quantity frozen I have entirely disappeared during the night, but for the assistance of a woman whom I engaged to supply water at intervals. At a maximum the mass of ice was at times about two inches square, and from the center to a half an inch thick. The gradual introduction of the water, by the funnel and valve cock, and of the pipe represented in the diagram, by which it was conducted to the cavity in the sheet brass, enabled me to accumulate a much larger mass than I could have otherwise produced. The brass band which embraces the inner jar near the brim, with the straps proceeding from it, serves to keep this jar in a proper position, concentric with the outer jar.

44. In this experiment, I employed an air-pump upon a new construction which I contrived a few years ago, and of which a description will be given in the Appendix.

45. Congelation, as effected in the experiments above described, may be assisted by the aid of any substance having a very strong affinity for water, as for instance chloride of calcium, clay, or whinstone, after having rendered anhydrous by ignition. Even parched meal or flour has been successfully employed in the process.

### *Of the Freezing of Mercury by the Vaporization of Ice.*

46. If a pear-shaped mass of ice containing the metal be suspended over a large surface of sulphuric acid, and a good exhaustion obtained, it will freeze the quicksilver which may be kept solid for several hours.

### *Wollaston's Cryophorus.*



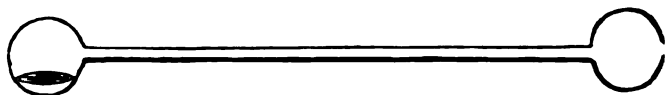
407. The adjoining figure represents the cryophorus, or frost bearer, an instrument invented by the celebrated Wollaston, in which congelation is produced in one cavity by rapid condensation in another, consequent to refrigeration.

408. In form, this instrument obviously differs but little from the palm glass, already described. (213, &c.) It is supplied by the same process with a small portion of water instead of alcohol; so that there is nothing included in it but water, either liquid or in vapour.

409. The cryophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will be frozen in a few minutes.

410. *Rationale.*—There is no difference between the causes of this phenomenon and those by which the congelation of water in vacuo is effected by the aid of sulphuric acid; excepting that in the one case the acid vapour is absorbed by the acid, in the other condensed by the cold. In either instance it is rapidly removed, and a proportionably rapid evaporation of the water ensues, abstracting the caloric of fluidity from the remaining portion.

*Large Cryophorus.*



411. This figure represents a very large cryophorus, the blowing of which I superintended, and by means of which I have successfully repeated Wollaston's experiment.

412. This instrument was about four feet long, with bulbs of about six inches in diameter.

• *Modification of the Cryophorus.*

413. Two flasks, of which the necks have flanged orifices, are so secured in a wooden frame that, by the pressure of screws, S S, and gum disks, the orifices of a tube are made to form with them several air-tight junctures. The orifices of the tube are furnished with brass flanges, which correspond with those terminating the necks of the flasks.



414. Midway between the junctures a female screw is soldered into the tube for the insertion of a valve cock V, by means of which, and a flexible tube extending to an air-pump, the flasks may be exhausted, and the apparatus closed. A small quantity of water having been previously introduced into one of them, if, while the exhaustion is sustained, the other flask be surrounded by ice and salt, the water will be frozen.

415. This apparatus may be applied to the purpose of desiccation, by placing the article to be dried in one receptacle, and quicklime, chloroform, or concentrated sulphuric acid in the other. The orifice of the receptacles may be made larger without inconvenience. Two large flasks, for instance, may be used.

*Chemical Combination as a Cause of Cold.*

11. Chemical union, although more frequently the cause of increased heat, is in many cases productive of the opposite effect.

12. There are few instances of chemical union, which are not accompanied by a change of capacity. Of the cause of such changes, we are ignorant, and of course have no more reason to wonder when, by an union of caloric, cold is the consequence of chemical reaction, than by an evolution of caloric, heat arises from the same source.

13. In the case of the solution of snow in concentrated sulphuric acid, by addition, we find these opposite effects resulting apparently from the cause. Under the same head of solution, as a cause of heat or cold, it is mentioned that nitre and nitrate of ammonia produce cold during their solution. This is equally true in the case of many other salts. But the most striking means of artificial cold, is the solution of ice, in consequence of the union between it and the more deliquescent salts, or the mineral acids.

14. It may be inferred, from the statements already made, that the nature of freezing water, or melting ice, is  $32^{\circ}$ ; and that when ice is added by other bodies at a higher temperature, it will continue to absorb from them the caloric necessary to its fusion, until it be all liquefied. It is evident that the minimum temperature which can be thus attained. But by mingling ice in a divided state, with certain salts or having a great affinity for water, and which form with it compounds in which the freezing point is lower than  $32^{\circ}$ , the mass will abstract caloric from adjoining bodies in a mode quite analogous to that in which ice has been seen to operate; while the minimum temperature attainable is as low as the freezing point is lower. Thus the freezing point of salt water is about zero of Fahrenheit's scale; consequently on mingling it with snow, the liquefaction of the resulting mass will proceed, at any rate above zero, to abstract caloric from all adjoining bodies until it is as cold as the mixture. By the addition of crystallized chloride of calcium, or of diluted nitric or sulphuric acid, to snow, a compound may be formed, of which the freezing point is below that at which mercury freezes, or  $-39^{\circ}$ . Housekeepers have latterly availed themselves of the use of salt, to remove ice from the marble steps at the entrance of dwellings; as in this way it may be detached without injury to the marble.

*Table of Freezing Mixtures.*

The following tables are taken from Thomson's Outline of the Philosophy of Heat and Electricity, page 191.

*Frigorific Mixtures without Ice.*

Mixture.	Parts.	Thermometer sinks,	Degree of cold produced.
of ammonia . . . . .	1	From $+ 50^{\circ}$ to $+ 4^{\circ}$ .	46
of ammonia . . . . .	1		
to of soda . . . . .	1		
to of soda . . . . .	9	From $+ 50^{\circ}$ to $- 7^{\circ}$ .	57
nitric acid . . . . .	4		
to of soda . . . . .	9		
of ammonia . . . . .	6	From $+ 50^{\circ}$ to $- 12^{\circ}$ .	62
nitric acid . . . . .	4		
of soda . . . . .	8		
of ammonia . . . . .	5	From $+ 50^{\circ}$ to $- 21^{\circ}$ .	71
nitric acid . . . . .	5		
of soda . . . . .	5		
of ammonia . . . . .	5	From $+ 50^{\circ}$ to $0^{\circ}$ .	50
nitric acid . . . . .	5		
of soda . . . . .	4		
of ammonia . . . . .	4	From $+ 50^{\circ}$ to $+ 3^{\circ}$ .	47
nitric acid . . . . .	4		
of soda . . . . .	4		

*Frigorific Mixtures with Ice.*

Mixtures.	Parts.	Thermometer sinks,	D co di
Snow, or pounded ice	2	From any temp. to $-5^{\circ}$ .	
Muriate of soda	1		
Snow, or pounded ice	12		
Muriate of soda	5	From any temp. to $-25^{\circ}$ .	
Nitrate of ammonia	5		
Snow	3		
Diluted sulphuric acid	2	From $+32^{\circ}$ to $-23^{\circ}$ .	
Snow	8		
Muriatic acid	5		
Snow	7	From $+32^{\circ}$ to $-30^{\circ}$ .	
Diluted nitric acid	4		
Snow	5		
Muriate of lime	2	From $+32^{\circ}$ to $-40^{\circ}$ .	
Snow	3		
Cryst. muriate of lime	1		
Snow	2	From $0^{\circ}$ to $-66^{\circ}$ .	
Cryst. muriate of lime	1		
Snow	3		
Cryst. muriate of lime	8	From $-40^{\circ}$ to $73^{\circ}$ .	
Snow	10		
Diluted sulphuric acid			

## STATES IN WHICH CALORIC EXISTS IN NATURE.

421. With two of the modes in which caloric exists in nature, the student of this Compendium has been made acquainted; and these are the modes of its existence generally recognised. As it exists in one of them it is called sensible heat, being susceptible of detection by the senses, or by the thermometer. In the other it is called latent heat, because the quantity sent in that mode of existence, is not open to those means of detection. even in this latent state, caloric is known to be influenced by temperature, being liable to be removed entirely from vapours, or liquids, by combination with colder substances; so as to render its subsequent presence, a proof of its previous existence in the matter from which it has been abstracted.

422. It seems to me, however, that, in some substances, caloric exists in a state in which it is wholly independent of external change of temperature. In this predicament I suppose it to reside in the nitrochlorates, and fulminates, and generally in all detonating compounds.

423. If, agreeably to the received chemical doctrines, we are to ascribe the explosive power of such compounds to combined caloric, it must be evident that its condensation in them is wonderfully great. Yet no good reason can be assigned for this prodigious condensation. It cannot be ascribed simply to the attraction of ponderable matter; since the same ponderable matter which confines it at one moment, liberates it in the next without adequate assignable cause.

424. Thus the presence of platinum sponge, a cold metallic compound, causes the caloric of a gaseous mixture of hydrogen and oxygen to be condensed explosively. An electric spark, or the contact of any ignited matter, produces the same result. The case of gunpowder, exploded by the ignition of the most minute portion of the mass, is equally unaccountable, and likewise the explosive recombination of water by a discharge from the galvanic wires, by which its decomposition may have been effected.

425. The almost irresistible extrication of oxygen in the gaseous



from oxygenated , by contact with the oxide of silver, is still more in point and even more surprising.

426. I conceive, therefore, that in organic compounds, caloric is held in a peculiar state, dependent on a hidden cause, of which the details would probably unfold many mysteries in galvanism and electro-magnetism, as well as in chemistry. I deem it more than probable that the cause of electricity is the principal agent in these mysterious phenomena.

## SECTION II.

### LIGHT.

427. It must necessarily belong to chemistry to treat of light, so far as it is productive of heat, deoxydization, and other chemical effects, and so far as it is evolved by chemical processes.

428. According to Newton, light is a subtile fluid, which is either radiated or reflected from every visible point in the universe, in consequence of its elasticity or the self-sustaining power of its particles.

429. It comes from the sun about ninety-five millions of miles, in eight minutes, nearly at the rate of two hundred thousand miles in a second.

430. Light appears to have no sensible weight. The products of the combustion of phosphorus, carbon, and other combustibles, appear fully equal in weight to the ponderable matter employed. It follows that the loss of the light and heat occasions no diminution of weight; yet enough is emitted by the flame of a candle or lamp to be perceived by many hundred millions of eyes. There is not a luminous point in the universe, from which a sphere of rays is not emitted, in radius equal to any distance from which that point may be seen.

431. According to Huygens, Euler, Young, Fresnel, and others, light is due to the undulations of a rare elastic medium, or ether, which pervades the universe. This opinion has, within the last forty years, gained the assent of a majority of men of science. The doctrine of Newton is, however, less difficult to comprehend, and serves sufficiently to associate the phenomena intelligibly. Besides, so long as we assume the existence of a material cause of caloric repulsion, (11, &c.) we cannot consistently explain the quick communication of heat (289, &c.) without supposing that the particles of caloric radiate from hot bodies, as do those of light from luminous bodies, agreeably to the Newtonian doctrine. But if caloric radiation be ascribed to the emission of material particles by hot bodies, it would be in-

consistent not to ascribe the analogous phenomena of light to a like cause. In obedience to these considerations I shall resort to this theory in the case of light as a chemical agent, not without a hope that the objections which have been made to it, may hereafter find an answer in some new view of the subject.

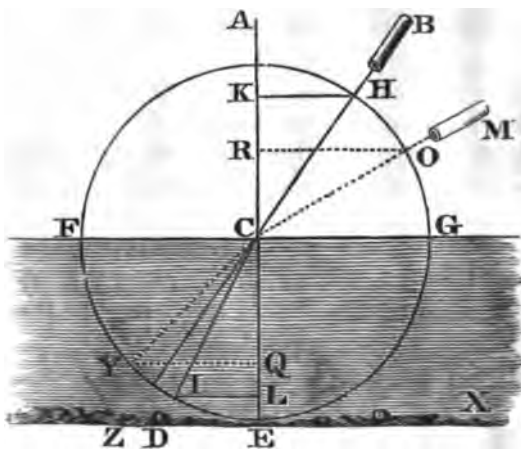
### *Of the Sources of Light.*

432. As a source of light, the sun is obviously much more prolific than as a source of heat; and it must be evident, that all the processes which produce ignition must also produce light.

433. There are some cases in which light is emitted without heat. As it comes to us from the moon, as excited by luminous insects, decayed wood, or the phosphorescent wave, it appears to be unaccompanied by caloric.

434. In the fire-fly, and in many other insects, light is evolved by vital action.

### *Refraction of Light.*



435. When a ray of light passes obliquely from a rarer into a denser medium it is bent *towards* the perpendicular direction. When the course of the oblique ray is continued from the denser medium into one which is rarer, it is bent *from* the perpendicular direction.

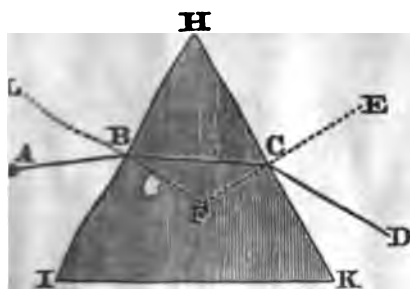
436. Suppose F G X Z to be a body of water. If a pencil of the solar rays enters the surface of the water perpendicularly at C, it will penetrate the water without deviating from its previous course; for whatever may be the attraction between the light and the water, it cannot cause any deflection, since it must act equally on either side of each ray. But should a pencil of rays passing through the air and penetrating the water at C, reach the bottom, it would shine on the pebbles at Z, whereas, it would shine upon Y, were the water removed. The light in this case, passing from a rarer into a denser medium, and entering the latter obliquely, is attracted by the denser medium most on the side nearest to it, and consequently is bent, or refracted, from their previous course.

About C, as a centre, describe the circle, F H E, and from A draw a diameter, perpendicular to the surface of the water. Let the lines B C, C I, represent the path of the light in passing from the tube to the bottom of the water. These lines intersect the circle, draw K H, I L, parallel to the surface of the water. The angle A C H, which the incident ray makes with the perpendicular, is the angle of incidence, and K H the sine of this angle. I C E is called the angle of refraction, and I L its sine. In the case of water, the sine I L is almost to be the sine K H, as 3 to 4; but were a mass of glass substituted for water, the sine of the angle of refraction to that of incidence would be as 2 to 3, the glass were replaced by a similar mass of diamond, the ratio would be as 2 to 5: the ratio being always invariable in the same medium, whatever be of incidence may be; for if the pencil of rays were to proceed to C, from at M, making the angle of incidence, A C M, and the angle of refraction, the sine, Y Q, would be the sine, R O, in the same ratio as I L to K H; and would hold good as before stated, whether F G X Z were water, diamond, crystal, or any other homogeneous and transparent refracting medium. The refraction, has been thus described as taking place during the passage of rays from air to denser media, equally ensues when light passes out of such media into the air; it is in air alone that it takes place; it is enough that the substances through which it passes be of different densities, or chemically different in their natures. Stable liquids or solids have been found to refract most powerfully. It was his discovery of the association between combustibility and refracting power, that led to Newton truly to infer the combustible nature of the diamond, from its sufficiency in causing refraction.

As an illustration of the case of light refracted, in passing out of denser into rarer, let us imagine the eye of an observer placed at the upper orifice of a, B, in the figure. Instead of the pebble, Z, which he would see if the water were removed, the pebble, D, will be seen by him. Hence the well known power of air in rendering an object visible, when, in the absence of the liquid, our view is intercepted by the side of the containing vessel; and hence likewise the image which a stick or cord presents to us, when seen partially under water.

*On the Refracting Influence of a Triangular Prism, and of a Plate or Pane of Glass.*

In passing through a plate of glass whose surfaces are parallel, the refraction of light sustains from one surface, is compensated by an opposite refraction by the other surface; but during its passage through a prism as represented in the following diagram, it is subjected to a concurrent refraction from two surfaces.



440. Supposing that the refracting medium, F G X Z, in the last figure, were bounded by air below as well as above, and its upper and lower surfaces were parallel, as in the case of a plate or pane of glass, a ray of light in passing obliquely through it, would be equally attracted, on one side, as it enters, on the other side as it emerges. Hence, after its emergence, it will proceed parallel to its original direction.

441. But should a ray fall upon a prism, as represented in the foregoing figure, in the direction of the line, A B; by the preceding demonstration, it will, on account of the obliquity of its surface, be refracted towards C, and emerging from C, obliquely to another surface of the prism, H C K, it will be again most attracted by that portion of the surface which it inclines. Consequently, it will be refracted so as to proceed in the direction C D.

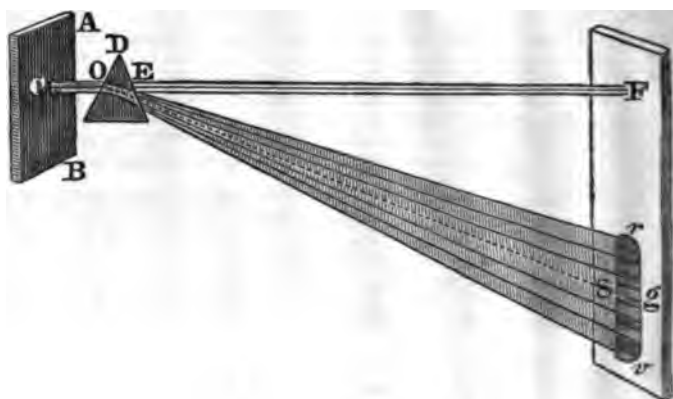
Thus it must be evident that the two surfaces of the prism have a concurrent influence in bending the rays from their previous course; while in the pane, the influence of one surface is compensated by that of the other.

The lines, L F and E F, being perpendiculars to the surfaces of the prism, the angle of incidence, and F B C, the angle of refraction, to the surface on which the rays enter the prism. F C B is the angle of incidence, and E C D, the angle of refraction to the surface from which the rays emerge.

*Dispersion of Light.*

444. Besides the refraction sustained by a pencil of rays, agreeably to the preceding illustration, they undergo another alteration, the effects of which are very pleasing, and, agreeably to the doctrine of Newton, highly instructive, being the foundation of his theory of colours.

445. Light appears to consist of particles of different kinds; each kind having the property of producing on the retina of the eye a peculiar impression, which being conveyed to the sensorium creates the idea of a colour. The rays thus capable of acting differently on the retina, seem to be unequally susceptible of refraction. Hence, in passing through the prism, they are separated from each other, forming a beautiful series of all the various colours of the rainbow, in an oblong figure called the spectrum. Under these circumstances, the rays are said to be dispersed, and the process by which they are separated is called dispersion.



446. Let A B represent a part of a window shutter of a room, into which light enters only through the hole C. If the light thus entering be received on a screen, a circular spot on it will be made luminous. But if a glass prism, D O E, be placed before the hole, so that the light may fall advantageously upon the prism, the rays, which had before produced the luminous circle, will be refracted and dispersed, so as to form the spectrum, *r g v*, consisting of the following colours, arranged in the following order—red, orange, yellow, green, blue, indigo, violet.

*Of the Heating, Illuminating, and Chemical Properties of the Rays.*

447. The red rays are found to be pre-eminent in heating power; the violet as remarkable for their superior influence in certain chemical changes, dependent on deoxidation. In the middle of the spectrum, the rays have the highest power of illumination.

448. Besides the rays thus mentioned, there are invisible, heat-producing rays beyond the red, and invisible rays producing deoxidation beyond the violet.

449. Agreeably to the observations of Herschel, to whom we are indebted for the discovery of these invisible rays, the greatest heating and deoxidizing power exists just beyond the limits of the visible spectrum; but from

experiments by Seebeck and Mellone, it appears that the location of the principal heating power is dependent on the nature of the refracting medium.

40. In the spectrum produced by crown or plate glass, the principal heat was in the red, and in that procured by flint glass, beyond the red; a variety of transparent liquid media having been made by the cavities of several hollow glass prisms, it is found that when a prism was occupied by water or alcohol the maximum of heat was in the yellow rays; when it is filled with sulphuric acid, or solutions of sal-ammoniac or corrosive sublimate, the maximum heat was in the orange.

41. Of the rays perceived by the eye, the red, being the least bent from the previous course, are obviously the least refrangible; and it is no less obvious that the violet, being the most bent, are the most refrangible; also that those rays, which are found equidistant from the red, and violet, have a mean refrangibility.

42. An opinion has been entertained by some philosophers that there are only three original and distinct species of light, which seems lately to be sanctioned by one of the most celebrated opticians of modern times. I allude to Sir David Brewster, whose opinions I shall give, by quoting them in his own language, from his *Treatise upon Optics*, page 68, American edition.

43. With the view of obtaining a complete analysis of the spectrum, I have examined the spectra produced by various bodies, and the changes which they undergo by absorption when viewed through various coloured media, and I find that the colour of every part of the spectrum may be changed not only in intensity, but in colour, by the action of particular media; and from these observations, which it would be out of place here to detail, I conclude that the solar spectrum consists of three spectra of equal lengths, viz. a red spectrum, a yellow spectrum, and a blue spectrum. The primary red spectrum has its maximum of intensity about the middle of the red space in the solar spectrum, the primary yellow spectrum has its maximum in the middle of the yellow space, and the primary blue spectrum has its maximum between the blue and the indigo space. The two minima of each of the three primary spectra coincide at the two extremities of the solar spectrum.

44. From this view of the constitution of the solar spectrum we may draw the following conclusions:—

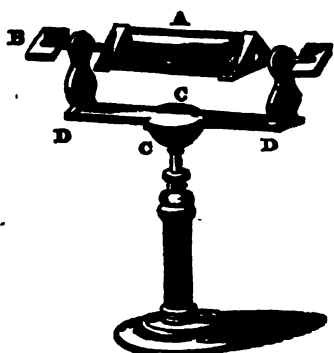
45. - 1. Red, yellow, and blue light exist at every point of the solar spectrum.

46. - 2. As a certain portion of red, yellow, and blue constitute white light, the colour of every point of the spectrum may be considered as consisting of the predominating colour at any point mixed with white light. In the red space there is more red than is necessary to make white light with the small portions of yellow and blue which exist there; in the yellow space there is more yellow than is necessary to make white light with the red and blue; and in the part of the blue space which approaches violet there is more red than yellow, and hence the excess of red forms a violet which is blue.

47. - 3. By absorbing the excess of any colour at any point of the spectrum above what is necessary to form white light, we may actually cause white light to appear at that point, and this white light will possess the remarkable property of remaining white after any number of refractions, and of being decomposable only by absorption.

Such a white light I have succeeded in developing in different parts of t  
These views harmonize in a remarkable manner with the hypothesis of t  
which has been adopted by many philosophers, and which others had  
its incompatibility with the phenomena of the spectrum."

*Triangular Glass Prism, conveniently mounted on a univers*



This figure represents a glass prism, mounted on a joint, supported by a brass plate, as to be well qualified for the dispersion of light, agreeably to the experiments alluded to in the principles.

A, the glass prism, supported at each end by a pivot.

B, B, handles by means of which the pivots are turned, so that the prism revolve.

C, C, ball and socket joint, upon which the plate

is moved so as to assume any serviceable position.

*Of certain Chemical Effects of Light.*

458. I have already adverted to the calorific influence of light, and to its power of producing chemical changes. Among these, the bleaching power of the solar rays is familiar to every body. In this process the rays exercise that modifying influence on the attractive force of the matter already alluded to. (20, 21.) Consequently a new arrangement of particles ensues in lieu of that which formed the colouring matter. Certain vegetable substances exposed to the sun in water, have been found to generate gas. Some metallic salts, especially nitrate of silver, are blackened by exposure to light, owing, as is ascertained, to a deoxygenation. A mixture of hydrogen and chlorine, in the dark, remain for a long time without combination; in the rays of the sun will explode. According to Davy, the power of producing this result exists only in the violet rays.

459. Other important processes in which chemical change is produced by the agency of light, will be mentioned as I proceed.

*Polarization of Light.*

460. This name has been given to a property of light which causes it often to be divided into two portions.

of which is transmitted, the other reflected, by the same piece of glass: or one portion sustains refraction in an ordinary degree, the other in an extraordinary degree. Again, all these properties are found to be commutable, so that the portion of the rays which is reflected in one case, may be transmitted in another; or that which in one case sustains the ordinary refraction, in another may undergo the extraordinary refraction, and vice versa.

461. These phenomena are ascribed to the different positions assumed by the different groups of rays, in consequence of which certain poles, which the lumeniferous particles are supposed to possess, are variously directed at different times, so as to determine their reflection, or transmission, or the degree of their refraction.

462. In consequence of this diversity of position, in the poles of light-producing particles, and the peculiar arrangement of the particles of certain transparent bodies, those portions of light, of which the poles are favourably situated for transmission, may pass through such bodies, when other portions, of which the polar positions are different, may be reflected; one group of the rays may undergo the ordinary, the other the extraordinary refraction. Yet after transmission, reflection, or refraction, the polarity of the groups of rays being reversed, those which were transmitted, or unusually refracted, in the first instance, may, in the second, be reflected, or only ordinarily refracted; while such as were reflected at first, or ordinarily refracted, may, in the second, pass through, or be unusually refracted.

463. Latterly, it has been ascertained by Professor Forbes of Edinburgh, that the non-luminous rays emitted by heated bodies, are susceptible of affections analogous to those ascribed to the polarization of light. As the phenomena in question are due to the reaction which takes place between masses and particles, agreeably to the definition at the commencement of this work, they belong to natural philosophy proper, not to chemistry. Yet a chemist must be indifferent to inquiries which tend to sanction, or reject, his theoretic deductions respecting the important and interesting phenomena of heat.

## OF PONDERABLE MATTER.

464. Whatever may be the real state of the case, it has been found convenient by chemists, during the last forty years, to assume the existence of three imponderable principles, in order to account for certain phenomena and associate them advantageously. The reasoning which tends to justify this course, has been already briefly stated. (10 to 22.) Of two of those principles, caloric and light, I have treated in the preceding pages. Of the other imponderable principle, electricity, whether statical or dynamic separate treatises will be supplied.

465. In the next place, I shall treat of that "*kind of matter which is endowed with weight, and which is in consequence recognised as material by the mass of mankind.*" (18.) This kind of matter may be generically designated as *ponderable*.

466. In treating of ponderable matter, it has been deemed expedient to designate substances, which are exclusively or generally the products of animal and vegetable organization, as organic, all other matter being designated as inorganic. Hence, *nominally*, two branches of chemistry have been created, called organic, or inorganic, accordingly as the objects of attention have been such as to justify the one, or the other designation. Yet it is undeniable that no accurate line of demarcation can be drawn between the branches thus distinguished. Substances produced by animal or vegetable life, may in several instances be obtained by the reaction of inorganic bodies; the phenomena in each branch are dependent on the same ultimate elements; and in almost all cases, those of organic chemistry are displayed by means of agents derived from the inorganic world.

467. Nevertheless, the separation of chemical science into the two branches in question, seems to me highly advantageous in practice. Few persons who are not chemists by profession, can acquire more than a general chemical knowledge of important facts, properties, elements, principles, and combinations, with so much theory as may be necessary to associate them. With those details and minutiae, of which organic chemistry mostly consists, it were useless to endeavour to impart a knowledge during the time allotted to an education, in which the attention of the learner is divided between several branches of science. But the acquisition of that degree of knowledge which it is reasonable to expect in organic chemistry, is quite easy to a student who is familiar with the inorganic department of this science; while to one ignorant of the latter, the smallest progress in the former is utterly impracticable.

468. This subject will be recurring to when I enter upon organic chemistry. Meanwhile, after treating of certain general properties of ponderable matter, or the means of ascertaining or observing them, I shall proceed with the chemistry of inorganic substances.



## OF CERTAIN GENERAL PROPERTIES OF PONDERABLE MATTER,

AND OF THE MEANS OF ASCERTAINING, OR OBSERVING  
THEM.

469. As introductory to the consideration of the individual inorganic substances, it will be expedient to treat of *Chemical Attraction, Definite Proportions, Specific Gravity, and the Mode of collecting and preserving Gases*, formerly designated as *Pneumatic Chemistry*. These subjects will be considered in the four following sections.

### SECTION I.

#### OF CHEMICAL ATTRACTION.

470. The word chemical has been used to designate the attraction which takes place between heterogeneous particles only. I object to this restriction of its meaning, because I consider it as affording a natural line of separation between chemical and mechanical philosophy, to consider the one as treating of the reaction of masses, or of masses and particles, the other of the reaction of particles only. Besides, the process of crystallization, of which I shall in the next place treat, arises from the reaction of homogeneous atoms;\* and it was among chemists that the investigation or observation of the laws and phenomena of crystallization originated. I consider the force which causes homogeneous atoms to cohere, whether in the crystalline form or otherwise, as a species of chemical attraction.

471. The attraction which takes place between homogeneous particles, is designated as *attraction of aggregation, attraction of cohesion, or homogeneous attraction*. The attraction which arises between heterogeneous particles, is called *chemical affinity, or heterogeneous attraction*.

*Of Attraction of Aggregation or Cohesion, or Homogeneous Attraction.* -

472. Of this kind is the force which enables bodies to resist mechanical division. Overcoming it does not alter the

\* I use the word particle only to designate those elementary portions of matter which cannot by any natural means be divided. Chemists use the word atom to signify either such a particle, or the smallest portion of a chemical compound, which can exist without decomposition. (472, 507, 550, 551.)

*chemical* nature of a substance. It is the cause of crystallization. (See note.)

### *Of Crystallization.\**

473. Almost all matter, in passing from the fluid to solid state, assumes regular forms called crystals. As it is inconceivable that homogeneous particles, or atoms, differ in size or shape, it is not wonderful that when united by the same attractive force, they should produce regular forms. To produce irregular forms, the atoms, the forces actuating them, should be irregular. In fact, the deposition of matter from solution, or on the evaporation of the solvent, is accelerated or retarded, a corresponding change ensues in the crystalline form. In this way various deviations arise from that primary form which is assumed under circumstances which allow the deposit to proceed at the same rate precisely. Those forms, which deviate from the primary form, are called secondary. The various steps by which they are generated from the primary forms, have been most ingeniously traced, or inferred by Haüy and others. In some instances, the primary primitive form has been developed by cleavage.

474. It was at one time the general impression, that every chemical compound had an appropriate crystalline form. Latterly it has been shown that certain substances quite different in their nature, as for instance, phosphoric and arsenic acid, assume the same forms in crystallization. Such substances are said to be *isomorphous*. In the introduction to Thomson's Inorganic Chemistry, several groups of isomorphous substances are mentioned.

475. Other things being equal, crystals are larger in proportion as their growth is slower. They shoot from extraneous bodies, as the sides of the receptacle, or from strings or sticks, in preference to crystallizing in an isolated manner. Agitation hastens their production but confuses them. The crystalline texture of some of the igneous rocks is attributed to slow cooling. The same material, fused, and allowed less time to cool, forms a glass.

\* The details of crystallography, as they have been presented by Haüy and others, are of themselves so copious as to require for their remembrance a greater effort of the mind than all the chemistry which I expect a candidate for a medical degree to acquire. It is evidently one of those subjects of which a copious knowledge can be imparted advantageously during a strictly medical education. The instrument which I shall endeavour to give upon this topic, will be extremely brief.

6. **Berzelius** that, if two flasks, both containing saturated solution of two parts of nitrate of potash and of sulphate of soda, be surrounded with ice or cold; on introducing a crystal of nitrate of potash into one and a crystal of sulphate of soda into the other, salts will be formed in each flask, of the same nature as that of the crystal introduced. Nitrate of potash will be crystallized exclusively in the flask first mentioned, and sulphate of soda as exclusively in the other.

**7. Crystals are found in nature and are produced artificially.**

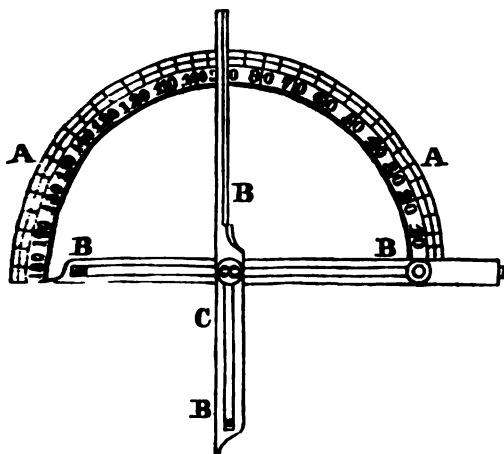
2. The precious stones & native crystals. Carbon of lime, common salt, and gypsum, are native products, often crystalline in form.

**Goniometer, or Angle Measure; an Instrument for measuring the Angles of Crystals.**

Crystals may appear to be exactly similar to the eye; but when compared by accurate instruments called goniometers, they will often be found to differ in angle. Of these instruments there are two constructions; one, being more in use, is of more general utility; the other, contrived by Wollaston, is used, but when skilfully employed is capable of giving more accurate results.

The instrument of the easiest application, and which is usually employed, is noted by the following engraving.

### *Of the Common Goniometer.*



The construction is founded upon the 15th proposition of Euclid, which de-  
 clares that the opposite angles, made by any two lines in crossing each other,  
 Hence it follows that the angles made by the legs,  $B B, B C B$ , of this  
 above and below the pivot on which they revolve, are equal to each  
 respectively, they may be made to close upon any solid crystalline angle, pre-  
 viously taken at  $C$ , till they shall be equal to it.  
 This angle is evidently equivalent to that of the crystal.

and is ascertained by inspecting the semicircle, A, graduated into 180 degrees, precisely in the same manner as a protractor.

482. The construction of goniometers is usually such as to allow the legs to be detached from the arch, in order to facilitate their application to crystalline angles and yet, so that they may be reapplied to the semicircle, without deranging them from the angle to which they may have been adjusted.

483. The piece of brass, in which the pivot is fastened, slides in a slit in each leg so as to permit them to be made of a suitable length, on the side on which the crystal is applied.

#### *Of Wollaston's Goniometer.*

484. The process by which angles are ascertained by means of Wollaston's goniometer is as follows:—

485. The crystal to be examined is attached to an axis, and so adjusted, by means of suitable mechanism, that the image of a window bar may be seen reflected from one of the crystalline faces, so as to coincide with a line (seen directly) drawn on the wall under the window, parallel to the window bar. By a partial revolution of the axis, and consequently of the crystal, a similar coincidence of the images of the bar and line is produced by means of another face of the crystal, being the next that first employed.

486. Meanwhile the number of degrees of a circle moved through, in changing the crystal from the first to the second position, is measured by an index on a graduated arch, and the degrees of the angle, which the surfaces make with each other thus ascertained.

#### *Various Modes of causing Artificial Crystallization.*

487. *Fusion followed by congelation.*—Instances: Crystallized sulphur, bismuth, antimony, zinc.

488. *Solution followed by evaporation in open vessels.*—Exemplified by salts, acids, alkalies, sugar.

489. *Solution with heat followed by refrigeration.*—Most of the substances which crystallize by evaporation, yield crystals in this way.

490. *Solution followed by vaporization at the boiling heat.*—Crystals may be thus obtained from many salts, but are always minute.

491. *Solution followed by saturation.*—Instances: Potash saturated by carbonic acid or chlorine.

492. *Sublimation.*—This comprises the idea of vaporization, and condensation into a state of solidity. Instances: Corrosive sublimate, calomel, iodine, arsenic.

493. *Solution followed by precipitation*; as in the case of the arbor Dianæ and arbor Saturni.

#### *Crystalline Specimens exhibited.*

494. A wooden arch, about fifteen inches high and a foot wide, encrusted with fine blue crystals of the sulphate of copper: also baskets constructed of bonnet-wire, curiously studded with elegant crystals of the same salt. Crystal of the ferropotassiate of potash, more properly called cyanoferite of potassium, suspended by a cord on which th

crystals we d. during their formation. (475.)  
 These crystals are of an agreeable lemon-yellow colour.

495. A crystalline congeries of alum, about a hundred pounds in weight. Baskets studded with crystals of the same salt.

496. Large cluster of crystallized borax.

497. Crystals of corrosive sublimate and calomel.

498. Crystals of sulphur, arsenic, bismuth, antimony, &c.

499. Various other crystalline bodies.

### *Of Decrystallization.*

500. It has been ascertained by Dr. Daniell that crystals may be partially developed by solution. When alum is slowly dissolved, its crystalline structure becomes very evident.

501. Specimen of decrystallized alum.

### *Of Water of Crystallization.*

502. The well known spiculæ, which, by their appearance on the surface of water, indicate incipient freezing, are crystals. In fact, it was from the Greek name for ice, *spenallac*, that the word crystal was adopted; as crystals were correctly considered as the products of a process analogous to freezing. This is strictly true in the case of crystals resulting from the congelation of matter from a state of fusion. Water enters into the constitution of many crystals which, when robbed of it by heat or desiccation, lose the crystalline form. The water thus situated is called water of crystallization. Some substances combine with water in different proportions, and consequently assume different forms; others crystallize with or without water, with a corresponding diversity of form. These results are dependent upon variations of temperature in the solvent at the period of the crystallization. At 86°, sulphate of soda crystallizes without, at 40°, with water of crystallization. Chloride of sodium, which is ordinarily anhydrous, is made to unite with water of crystallization at 8° below zero.

503. Crystals usually retain within their crevices a minute portion of the solution in which they have been crystallized. In the decrepitation of chloride of sodium and other anhydrous salts when heated, from the vapori-

zation of the water so retained. The larger the crystals, the more they are liable to this impurity.

*Of the Consequence of excluding the Air from a saturated Solution of Sulphate of Soda while boiling.*

504. If a flask be sealed, so as to be air-tight, while containing a *boiling saturated solution of Glauber's salt*, (sulphate of soda,) the solution will remain liquid, so long as undisturbed, but on the admission of the air, will often become a compact crystalline mass within a few seconds. In other cases, it will continue liquid for some time, even for 24 hours, and may then crystallize on being poured out of the flask. Sometimes it crystallizes in the neck of the vessel while the operator is pouring it out; at others, allowing a crystal or other body to fall into the solution, causes crystals to shoot. No satisfactory explanation has been afforded of this phenomenon. It seems as if the repulsive and attractive powers were so nearly balanced as to enable a slight external force to determine the preponderancy in favour of the latter. That there is an evolution of caloric, consequent to the congelation, is rendered evident by a rise of temperature.

*Experimental Illustration.*

505. Several glass flasks being made about two-thirds full of a saturated solution of Glauber's salt, and sealed up air-tight, the solution remains liquid until the air is admitted. It then crystallizes either spontaneously, or from slight causes.

OF CHEMICAL AFFINITY, OR HETEROGENEOUS ATTRACTION.

506. This attraction is never subdued mechanically, unless when nearly balanced by repulsion; as in the case of compounds which may be exploded by percussion, (29,) or of elastic fluids combined with liquids. (240.)

507. To sever elements, united by chemical affinity, the finest edge producible by human art is utterly incompetent. Thus, chalk consists of lime and carbonic acid; vermilion, of sulphur and mercury. Yet when reduced to powders perfectly impalpable, the minutest particle, whether of chalk or vermilion, contains the same ingredients as the mass, and in the same proportion.

*Different Cases of Affinity.*

508. *First Case—Simple Combination.*—A and B, two heterogeneous substances, unite and form the compound AB.

*Instances.*

509. Copper with zinc forms brass.  
 510. Copper with tin forms bronze.  
 511. Antimony with lead forms type metal.  
 512. Magnesia with sulphuric acid forms Epsom salt, or sulphate of magnesia.  
 513. Soda with sulphuric acid forms Glauber's salt, or sulphate of soda.  
 514. With mercury, various metals form amalgams.

*Experimental Illustration.*

515. A portion of gold leaf, being triturated with mercury, disappears, forming a chemical compound with the mercury, in consequence of the inherent attraction or affinity between the heterogeneous particles.

516. *Second Case of Affinity.*—Called *single elective attraction, or simple affinity.*

517. A and B, two heterogeneous particles, being united in the compound AB, another particle, C, being blended with them in solution, unites with one of them, as A, to the exclusion of B.

518. In this case, C is said to decompose AB, and to have a greater affinity for A than for B.

*Experimental Illustration.*

519. Potash being added to a solution of sulphate of magnesia, the magnesia precipitates in white flocks. A like result takes place, on adding a solution of potash to a solution of sulphate of alumina.

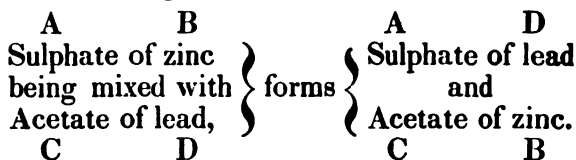
520. *Rationale.*—Sulphate of magnesia consists, as its name implies, of sulphuric acid and magnesia. The affinity existing between the potash and the acid being greater than between the acid and the magnesia, the latter is disengaged from combination, and, being by itself insoluble, precipitates. An analogous explanation will apply in the case of the alumina. In each case, the affinity of the acid

for the alkali, predominates over that of the acid for the earth.

521. *Third Case of Affinity.*—Called *double elective attraction, or complex affinity.*

522. The compound formed by the particles A and B being blended in solution with the compound formed by C and D,—A combines with D, and B with C.

*Experimental Illustration.*



523. *Fourth Case of Affinity.*—A and B being in union C, added in *excess*, combines with both A and B.

524. When ammonia is added to certain solutions of metallic salts, those of copper or silver for instance, it operates at first as the potash does in the case of single elective attraction abovementioned, and the oxide of copper or silver precipitates. But if the ammonia be added in such quantity, as that, after all the acid shall have been saturated, there shall be an excess of alkali, this excess will combine with the precipitated metallic oxide, forming with it a compound which is immediately dissolved. Hence the menstruum which is at first rendered turbid, afterward becomes clear, and, in the case of the copper, assumes a beautiful and characteristic blue colour.

*Experimental Illustration.*

525. Liquid ammonia being poured into a solution of copper, at first precipitates the metal in greenish flocks but, when the alkali is added in excess, these flocks disappear, and a blue solution results.

*Additional Illustrations of Chemical Affinity.*

526. In order to show the wonderful power of chemical reagents in producing striking changes, some additional exemplifications of chemical affinity will here be given. This exhibition may excite curiosity in the learner and



afford gratification to him, although unprepared to understand the intricate play of affinities by which the results are accomplished.

### *Experiments.*

527. Silver precipitated by mercury, mercury by copper, and copper by iron.

528. Conversion of two liquids into an adhesive mass by mingling sulphuric acid with a solution of chloride of calcium or nitrate of lime.

529. Solution of ferroproussiate of potash, added to solutions of copper and iron.

530. Solution of chromate of potash, added to solutions of lead, mercury, and silver.

531. Ammoniacal nitrate of copper or silver, added to arsenious acid.

### *Of Cohesion as an Opponent to Chemical Combination.*

532. There are many substances, among others carbon, which, under certain forms, in consequence of greater hardness, are much less susceptible of chemical reaction, than under others. Thus the diamond, anthracite, charcoal and tinder, are varieties of carbon, which are endowed with a susceptibility of combustion inversely as their hardness. Tinder is proverbially ready to take fire, while the diamond is only to be ignited by the aid of extreme heat, and an unusual supply of oxygen. Every body knows how much less susceptible of being acted upon by solvents, are bricks, porcelain, or stone ware, than the earthly materials out of which they are made. In these cases, it would really appear that the attraction between the homogeneous atoms counteracts the heterogeneous affinity which would sever them. Yet I conceive it to be an error to confound the obstruction to chemical reaction thus created, with that which arises from the restriction of the surface in contact with the solvent. Other things being equal, there will evidently be more action in proportion as the points of contact are multiplied, and vice versa. Thus the action of an acid will be less rapid upon a metallic ball, than upon the same weight of metal in the state of foil, fine wire, or turnings; although the attraction of the homogeneous

particles is quite as energetic in the one case as other.

*Effects of Mechanical Division experimentally illustrated.*

533. If a ball of brass be put into one glass, and half its weight of brass filings or turnings into another, adding nitric acid to both, a violent effervescence ensues in the one, while in the other, the reaction will be discernible.

*Influence of Solution in promoting Chemical Reaction, experimentally illustrated.*

534. Tartaric acid and a carbonate, although intimately intermingled in a pulverulent state, do not react until dissolved, when a lively effervescence ensues.

*Exception to the Law that Chemical Action requires Fluidity, experimentally illustrated.*

535. If slaked lime and muriate of ammonia in powder be mixed, the pungent fumes of ammonia will be perceived.

*Tables of Affinity.*

536. These consist of the names of a series of substances, placed in a column, in the order of their affinity for any one substance of which the name is at the head of the column. The following is an example:—

*Sulphuric Acid.*

Baryta,  
Strontia,  
Potash,  
Soda,  
Lime,  
Magnesia,  
Ammonia.

## SECTION II.

## OF DEFINITE PROPORTIONS.

537. The proportions have been long known to be invariable, in which substances must be mixed in order to saturate each other, or to produce a compound in which the peculiar characters, or affinities of the ingredients, are extinguished.

538. When substances combine in other proportions than those of saturation, their ratio is no less definite and constant.

539. There is not in any case, except the peculiar one of solution, an indefinite gradation in the proportions in which bodies combine. There are rarely more than four gradations.

540. The number, representing the least proportion in which a substance is known to combine, will, in a great majority of cases, divide the numbers representing the greater proportions without a fraction; and where this result is unattainable, it will still be found that the larger proportion may be divided by the half of the lesser without a remainder.

541. Let A, B, and C be certain substances, and let X, Y, and Z be other substances, severally having an affinity for either A, or B, or C. Let each of the former and each of the latter be combined in the least possible proportion. Consequently, the least combining proportion of each substance will be found three times. It will appear that the proportions of A, B, and C found by combining them with X, will be in the same ratios to each other, as the proportions found by combining them with Y, or Z; and reciprocally, that the proportions of X, Y, and Z, will have the same ratios, whether ascertained by their combination with A, B, or C.

542. When, instead of ascertaining the least combining proportions of six substances, the experiment has been extended to any larger number, the same uniformity has been found to prevail in the ratios of the numbers representing those proportions. It has also been found that when numbers are ascertained which express the ratio of the least combining proportions of a variety of substances to any one substance, as for instance to oxygen, those

numbers will express the ratios of the least combining portions of the substances in question, to each other.

543. Numbers representing *least combining proportions* are called *chemical equivalents*. As they are merely expressive of ratio, they may be multiplied by any common multiplier, or divided by any common divisor, without affecting their correctness.

544. They are usually so computed as to make the equivalent of oxygen, or of hydrogen = 1. As the valents of these substances are as 1 to 8, it follows, if hydrogen be represented by unity, oxygen will be 8; if oxygen be unity, hydrogen will be 0.125, or one-eighth. Consequently, equivalents, formed upon either system, may be converted into those corresponding with the other, either by multiplying or dividing by 8.

545. By Berzelius, Wollaston, and Thomson, the former has been made the standard. Berzelius assumes it as 8, Wollaston at 10, and Dr. Thomson at 1. The difference between the equivalents founded upon these numbers, is in the position of the decimal point.

### *Of Tables of Chemical Equivalents.\**

546. In these, the equivalents of all known bodies, so far as ascertained, are arranged alphabetically. Such tables are of great utility in practical chemistry. The analytical chemist may frequently resort to them with advantage. They enable him to store his memory with facts adequate to the solution of a great number of questions which must necessarily arise. If he wishes to know the relative weights of any two substances he must take to form a compound, he has only to recollect, or to look for, their equivalents in the table, and seek a solution by the rule of three. If he knows the equivalents of the substances as to each other, he can find the quantities of them to be used. Should it be required to produce only a certain weight of a compound, then the equivalent of the compound is to that of either ingredient, so is the weight of the compound required to the requisite weight of either ingredient.

547. In order to know how much of the proper reagents he must use to effect a decomposition, he has only to employ them in the ratio of their respective equivalents.

\* See Appendix for a Table of Equivalents.

48. Moreover, when the proportions, afforded by analysis, do not harmonize with well ascertained equivalents, we are warned of the existence of some inaccuracy, which in many cases may be safely corrected so as to make them accord with them.

### *Wollaston's Scale of Equivalents.*

This instrument is so constructed that the computation requisite in the use of equivalents is performed by a slide. It has been mentioned that equivalents may be expressed in any numbers having the same ratios to each other as the least combining proportions of the substances which they represent. The slide enables us to adopt any such numbers as may be convenient. Equal distances on the slide give the same ratios in different numbers. By moving the slide, we vary one equivalent to 100, for instance, and the other equivalents vary proportionably.

### *Of the Atomic Theory.*

Extension has been proved to be infinitely divisible, and it is not possible to suppose that the matter, comprised within any given limits, may be divided into as many subdivisions as the space in which it is contained. On the other hand, it is obvious, that *mechanical* division must be limited by the imperfection of the edges or surfaces employed to accomplish it.

Were atoms chemically divisible ad infinitum, any one substance, however small in quantity, might be diffused, in a state of chemical combination, throughout any other, having an affinity for it, however great; for the particles in the latter would exercise a stronger affinity than another could be unreasonable to suppose that each should not have its share. That such a diffusion is impracticable must be evident from the fact that the number of definite proportions to which substances in combination are restricted, as already mentioned when upon the subject of equivalents. Hence elementary atoms are not considered as liable to an infinite subdivision, either by chemical or mechanical agency. (539.)

The ratios of the equivalent numbers are supposed to be dependent on the relative weights of the atoms of the elements which they appertain. Thus the fact that 32 parts by weight of sulphur saturate as much of any acid as 48 parts of potash, is explained by supposing that the weights of the smallest atoms of those alkalis which combine with sulphur are to each other as 32 to 48.

In like manner it is explained that, when neutral salts are made to decompose each other, no excess of either ingredient is in any case observable. The lime in nitrate of lime is to the potash in an equivalent of the sulphate of potash, as 28 to 48, yet neither is the lime able to take the place of the potash, nor is there too much potash to decompose all of the lime. This result is intelligible, if we suppose that, in the decomposition, just adequate for reciprocal decomposition are employed, an equal number of atoms of each salt; the one containing as many atoms of potash weighing 48, as the other contains atoms of lime weighing 28.

The same explanation applies to the fact that, while the sulphuric acid in sulphate of potash is to the nitric acid in the nitrate of lime as 40

to 54, yet there is neither too much of the latter nor too little of the former, to produce neutral compounds with the bases to which they are generally transferred.

555. On account of the hypothetical association of the numbers, denoting the least proportions in which bodies are known to combine, the supposed relative weight of their atoms, those numbers are as known by the appellation of *atomic weights*, as by that of *chemical valents*.

### *Of Chemical Symbols.*

556. I shall translate from Berzelius an account of the symbols which he has devised, and which it would be well to understand, as they will be met with. Objections have been made to some part of his plan, but generally I believe it will be expedient to adhere to it; since whatever Berzelius recommends, awakens the attention of chemists universally, and cause his symbols to be generally understood throughout the chemical world.

557. "We select (says he) as symbols the initial letters of the names of bodies. When the names of several bodies have the same initial we add to each a letter which it has not in common with the rest; as an instance, C signifies carbon, Cl chlorine, Cr chromium, Cu copper, &c. But when, however, the names of a metallic and non-metallic element commence with the same letter, no additional letter is added to the former. But when two non-metallic elements have a common initial, it is necessary to distinguish one by means of an additional letter. Thus, to distinguish chlorine, bromine, and silicon, severally, from carbon, boron, and so on the symbols of the former are Cl, Br, and Si, while those of the latter are simply C, B, and S.

558. "The number of atoms is designated by cyphers. A cypher placed to the left multiplies all the symbols to the right, as far as the first cypher or the whole formula. A little cypher, situated to the right of a symbol and a little above its level, multiplies that symbol only. Thus  $S^2O$  signifies *one* atom of hyposulphuric acid, consisting of two atoms of sulphur and five of oxygen; while  $2S^2O^5$  signifies *two* atoms of the same acid. In such cases as that just cited, in which two atoms of the radical are combined with one, three, or five of oxygen, the expression for the former two is abbreviated advantageously by having a specific sign for a double atom. The sign which I have adopted for this purpose, is a dash across the lower part of the symbolic letter. Thus P signifies a single atom,  $\underline{P}^2$  a double atom of phosphorus. Compound atoms of the first order are expressed in the following example of sulphate of copper  $Cu\ O + SO^2$ . The sulphate of the sesquioxide of iron would be expressed by  $2Fe\ O^3 + 3S^2O^5$ .

559. "It may be expedient to designate the number of atoms of a radical by dots placed over the letters symbolic of radicals. Thus we may designate the sulphate of copper by  $Cu\ \ddot{S}$ , the trisulphate of the sesquioxide of iron, by  $2\ Fe\ \ddot{S}^3$ ."

\* Instead of placing the dash across the lower part of the letter, it is generally placed under it, as the former mode requires type cast for the purpose.

*List of the Atomic Weights of the Simple Ponderable Substances,  
together with their Symbols.*

502. As the atomic numbers are practically useful, enabling us to know the proportions in which substances are combined, or in which they should be used to produce compounds, it is advantageous to commit them to memory as far as possible. The whole number of substances recognised as elementary, agreeably to the present state of our knowledge, is fifty-four. These, little more than half are of sufficiently frequent recurrence either in speculation or in practice, to make it desirable to remember their numbers. I will quote them, therefore, in two distinct tables. Those of which knowledge is likely to be rarely in demand, I have subjoined in smaller type. The symbols are given in a separate column. In obedience to the example of the British chemists, I employ Po and So, instead of K and Na, the symbols of potassium and sodium.

	Symbol.	At. Wts.		Symbol.	At. Wts.
Aluminium	Al . . .	14	Lithium	L . . .	6
Antimony	Sb . . .	64	Magnesium	Mg . . .	12
Arsenic	As . . .	38	Mercury	Hg . . .	202
Barytes	Ba . . .	69	Nitrogen	N . . .	14
Bismuth	Bi . . .	71	Oxygen	O . . .	8
Borac	B . . .	11	Phosphorus	P . . .	16
Bromine	Br . . .	78	Platinum	Pl . . .	99
Calcium	Ca . . .	20	Potassium	Po . . .	40
Carbon	C . . .	6	Selenium	Se . . .	40
Chlorine	Cl . . .	36	Silicon	Si . . .	8
Copper	Cu . . .	32	Silver	Ag . . .	108
Fluorine	F . . .	18	Sodium	So . . .	24
Gold	Au . . .	200	Strontium	Sr . . .	44
Hydrogen	H . . .	1	Sulphur	S . . .	16
Iodine	I . . .	126	Tellurium	Te . . .	64
Iron	Fe . . .	28	Tin	Sn . . .	59
Lead	Pb . . .	104	Zinc	Zn . . .	32
Mercury	Cd . . .	56	Osmium	Os . . .	100
Magnesium	Ce . . .	46	Palladium	Pd . . .	53
Manganese	Cr . . .	28	Rhodium	R . . .	52
Mercury	Co . . .	30	Thorium	Th . . .	60
Nickel	Ta . . .	185	Titanium	Ti . . .	24
Platinum	G . . .	18	Tungsten	W . . .	95
Potassium	Ir . . .	99	Uranium	U . . .	217
Silver	Mn . . .	28	Vanadium	V . . .	69
Sodium	Mo . . .	48	Yttrium	Y . . .	32
Sulphur	Ni . . .	30	Zirconion	Zr . . .	34

appears from some experiments made by Messrs. Petit and Dulong, that the specific heat, or specific heats, of all elementary atoms are the same; so that the specific heat of any one congeries of atoms be less than that of another having the same weight, it is because the atoms of the one being heavier than those of the other, are fewer of them in the same weight. Hence the capacities, or specific heats, of equal volumes of elementary substances are greater, as the weights of the atoms are less: so that if, in the case of each, its atomic weight be multiplied by its specific heat, the product will in general be so nearly the same, that the difference may be ascribed to the inaccuracy unavoidable in experimental investi-

respecting this highly important and interesting inference of Petit and Dulong. A. D. Bache has endeavoured to show in an article published in the

Journal of the Academy of Natural Sciences, that multiplying the equivalents of twelve principal metals into their specific heat, gives results so widely deviating from uniformity as to take all plausibility from the hypothesis that the atoms of simple bodies have the same specific heat.

563. Dr. Thomson has observed that this law is more likely to be true, since it holds good without doubt in the case of the gases; and that if it be true we have only to divide the specific heat of hydrogen by the atomic weight of any body, to find its specific heat. Moreover that the specific heats thus found agree very nearly with those ascertained experimentally.

564. From the researches of Faraday, it appears that the quantity of the voltaic fluid given out during the solution of various metals, is in the ratio of their atomic weights. It would seem, therefore, as if the imponderable atmospheres, both caloric and electricity, are held by atoms in the same equivalent proportion.



### SECTION III.

#### OF SPECIFIC GRAVITY.

565. A clear idea of specific gravity is indispensable to a chemist. *Gravity* and *weight* are synonymous words; but the term *specific gravity* is used to signify the ratio of *weight* to *bulk*. Hence the object of all the processes for ascertaining specific gravities, is either to ascertain the *weight* of a *known bulk*, or the *bulk* of a *known weight*; for whether the substances whose specific gravities are to be found be reduced to the same weight and then measured, or be reduced to the same bulk and then weighed, the ratio of their weights to their bulks will be discovered. If reduced to the *same bulk* and *weighed*, their *specific gravities* will be *directly* as the *weights*. If reduced to the *same weight* and *measured*, their *specific gravities* will be *inversely* as their *bulks* thus ascertained.

566. Supposing a like bulk of each kind of matter in nature to be weighed, the results, numerically stated, would represent their specific gravities. But since it is not possible to procure an exactly similar bulk of each kind of matter, it is necessary to resort to another mode of reducing their bulks to a common measure. The method adopted in the case of solids and liquids, is to divide the weight of a given bulk of each body of which the specific gravity is to be found, by the weight of a like bulk of water. This in fact may be stated as the general rule for ascertaining specific gravities.

567. Thus on dividing the weight of any bulk of copper by the weight of a like bulk of water, the quotient is 9. This, therefore, is received as the specific gravity of copper. By a similar procedure, in the case of silver, the quotient is 10.5, in the case of mercury 13.6, in the case of gold 19.3: consequently, these numbers are considered as representing the specific gravities of those metals.

568. If the body be lighter than water, as in the case of cork which is only about one-fifth as heavy, the quotient, being less than one, is expressed by a decimal fraction. Thus the specific gravity of cork may be stated to be .2.

569. The gravity of water has been assumed as the standard, because this liquid may always be obtained sufficiently pure; and it is generally easy to ascertain the weight of a quantity of it, equal in bulk to any other body.

570. The weight of a quantity of water, equal to the body in bulk,



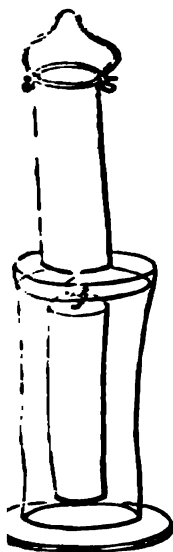
to the resistance which the body encounters in sinking in water. If we can ascertain, in weight, what is necessary to overcome the force which a body encounters in sinking in water, and divide by the weight thus ascertained, the weight of the body, we shall have its specific gravity.

1. In the case of a body which will sink of itself, the resistance to its sinking is what it loses of its weight when weighed in water.

2. In the case of a body which will not sink of itself, the resistance to sinking is equivalent to its own weight, added to the weight which is used to make it sink.

*Experimental Demonstration that the Resistance which a Body encounters in sinking in any Liquid, is just equivalent to the Weight of a portion of the Liquid equalling the Body in bulk.*

573. This proportion may be experimentally demonstrated, by means of an apparatus represented by the following figure.



574. The cylinder, represented as surrounded by the water of the vase, is made to fit the cavity of the cylinder suspended over it so exactly, that it enters the cylinder with difficulty, on account of the included air, which can only be made to pass by it slowly. It must, therefore, be evident, that the cavity of the hollow cylinder is just equal in bulk to the solid cylinder.

575. Both cylinders (suspended as seen in the figure) being counterpoised accurately upon a scale beam, let a vessel of water be placed in the situation of the vase. It must be evident, that the equiponderancy will be destroyed, since the solid cylinder will be buoyed up by the water. If water be now poured into the hollow cylinder, it will be found that, at the same moment when the cavity becomes full, the equiponderancy will be restored, and the solid cylinder sunk just below the surface of the water.

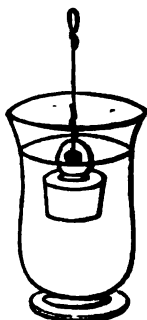
576. Hence it appears that the resistance which the solid cylinder encounters in sinking in the water, is overcome by the weight of a quantity of water equal to it in bulk. It must be evident, that the same will be true of any other body, and of any other liquid.

**71. Rationale.**—When a solid body is introduced into an inelastic fluid, on withdrawing it a hole is left, which remains vacant of the solid body; but no sooner is a body which has been introduced into a liquid withdrawn, than the liquid is found to fill up the space from which it had been removed.

72. It is evident that the force which liquids thus exert to re-enter any space within them from which they are forcibly excluded, is precisely equal to the weight of a quantity of the liquid commensurate with that space; and when the space is re-occupied by the liquid, the equilibrium is restored. Consequently, every body, introduced into a liquid, experiences from it a resistance equal to the weight of a quantity of the liquid, commensurate to the cavity which would be produced, supposing the liquid frozen about the solid mass, split open so as to remove it, and the fragments put together again; and the cavity thus created must obviously be exactly equal to the

bulk of the body. It follows, therefore, that the resistance which encounters in sinking within a liquid, is equivalent to the weight of the liquid, equal in bulk to the body.

*Method of ascertaining the Specific Gravity of a Body heavier than Water.*



579. Let the glass stopple, represented in the figure, be the body. First counterpoise the means of a scale beam and weights, suspending metallic wire. Place under the stopple a vessel of water; at the temperature of  $60^{\circ}$ , and lower than that if the stopple were not resisted by the water be immersed. Add just as much weight as will the resistance which the water opposes to the sinking of the stopple, and render the beam again horizontal by the weight by which the stopple had been previously counterpoised, by the weight thus employed to sink the stopple the specific gravity.

580. *Rationale.*—The weight requisite to sink the stopple measures the resistance to its being sunk in water, and this it has been shown is equal to the weight of a bulk of water equal to that of the stopple. Of course, pursuant to the general rule, it is necessary to see how often this weight is contained in the weight of the stopple, to ascertain its specific gravity.

*Method of ascertaining the Specific Gravity of a Body lighter than Water.*



581. Let a small glass funnel be suspended from a scale beam, and counterpoised so as to be just below the surface of some water in a vase, as represented in the diagram.

582. If, while thus situated, a body lighter than water, such as a small cork for instance, be thrown up under the funnel, the equilibrium will be subverted. Ascertain how much weight will counteract the buoyancy of the cork, and divide its weight by the sum. This will be the answer.

583. *Rationale.*—The force with which the water presses against the funnel, is equal to the difference between the weight of the funnel and the weight of the bulk of water it displaces. Of course, to ascertain the force which will rise by using just weight enough to counteract the buoyancy, adding this weight, so ascertained, to that of the funnel, will have the weight of a bulk of water, equal to the bulk of the cork displaced. Dividing the weight of the cork agreeably to the general rule, the specific gravity of the cork will be found.

*Method of ascertaining the Specific Gravity of a Liquid.*

584. Let the stopple be counterpoised, exactly as above directed, excepting that it is unnecessary to take any account of the weight of the stopple.

585. Having, in like manner, ascertained how much weight

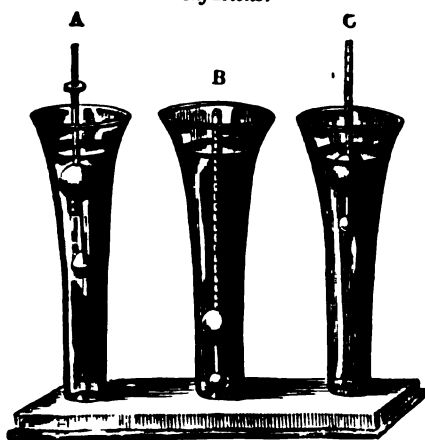
in a given liquid, divide this by the weight required to sink it in the water. The quotient will be the specific gravity sought.

¶ *Rationale.*—It has been proved that the resistance to the sinking of a body in any liquid, is precisely equal to the weight of a bulk of the liquid, equal in bulk to the bulk of the body. Ascertaining the resistance to the immersion of the same body in different liquids, is, therefore, the same as ascertaining the weights of bulks of those liquids, equal to the bulk of the body, or, of course, to each other. And if one of the liquids be water, dividing the weight of this by the weights of the others, gives their specific gravities.

If the stopple be so proportioned as to lose just one thousand grains in immersion in water, division is unnecessary; as the weight of the liquid obtained in grains, which are thousandths by the premises. A float of exactly the same weight as the stopple, may be employed in juxtaposition.

In these experiments, the liquid should be as near 60° of Fahrenheit as possible.

*water for Alcohol, for Acid, Saline, and other Solutions, and for Vegetable Infusions.*



In these a constant weight is used to a certain extent, and the differences of resistance are estimated by the quantity of the stem immersed. In those instruments of construction where several weights are employed, the effect is the same as if the stem of the instrument were lengthened as many times as the number of the weights attached to it.

The preceding engraving represents three hydrometers, A, B, and C, contained in a common vessel. B and C are of glass, and A of metal.

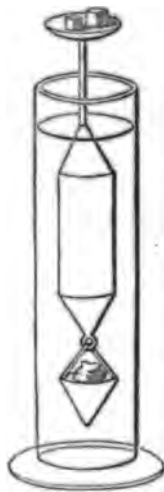
A is intended for liquids heavier than water; C, for those which are lighter. The graduation commences at that point of the stem, to which the instrument is immersed in distilled water. It must of course commence at the top of the stem for liquids heavier than water, and at the bottom of the stem for liquids lighter than water. In the latter case, as in that of spirituous liquors or ethers, the strength of the stem is stronger; but the opposite is true in the case of acid and saline solutions. The more of the stem is immersed from these, the stronger they are. The instruments are represented as being in pure water.

This is an hydrometer of a form much used in this country and in England, both for the determination of the specific gravity of acids and infusions of vegetable matter. The stem is virtually lengthened by several small weights, which may be slipped on and off at pleasure.

593. The whole difference between the weight of water and that of the spirit is equal to about two parts in ten. Of course, an hydrometer for spirit have on its stem a scale of more than two hundred parts, in order to give the gravity of any liquid consisting of water and alcohol. To render such gravity sufficiently discernible, the stem would have to be of very inconvenient length. This is obviated by using different weights. When the heaviest weight is on the stem, the whole of the stem stands above the surface in distilled water. If the liquid contains enough spirit to allow the whole of the stem to sink in it, supporting this weight, a lighter weight may be used; and when the stem again be wholly merged, this last mentioned weight may be exchanged for one still lighter. Supposing the stem graduated into fifty parts, three weights would give fifty each, and the stem unloaded, fifty more. Were the stem graduated into one hundred parts, nineteen weights would give one hundred and ninety parts, and the stem unloaded, ten more.

594. An instrument, sometimes called a saccharometer, but precisely of the same principle, is used for infusions of vegetable matter, especially for the wort of brewers and distillers, excepting that the scale begins at the top of the stem, which coincides with the surface of pure water, at sixty degrees Fahrenheit. When the infusion is strong enough to support the whole of the stem above its surface, a weight is to be added heavy enough to bring the graduated part of the stem into the liquid. And, in like manner, if the infusion is found stronger, weights still heavier must be added; the process being perfectly analogous to, but the converse of that described in the case of alcohol.

*Nicholson's Gravimeter, for ascertaining the Specific Gravity of Solids, either heavier or lighter than Water.*



595. The accompanying cut is a representation of Nicholson's Gravimeter, the construction of which is sufficiently obvious.

596. On the upper scale of the instrument, whilst the vessel is full of water, place any body, the specific gravity of which is to be found—a piece of coin for instance—and add as much weight to the same scale as will sink the gravimeter, until the mark upon the stem coincides with the surface of the water. The coin is then to be transferred to the lower scale, and as much weight added to the upper one as will cause the mark upon the stem to coincide with the surface of the water. This weight is obviously just equivalent to the resistance which the coin encounters in sinking in the water. Let this weight be called A.

597. In the next place, the body is to be removed from the lower scale, and as much weight, B, again added to the lower scale, as will cause the mark upon the stem to coincide with the surface of the water. Of the weight first employed, no need be taken; but the weight, A, and the weight, B, the second and third steps of the process, are to be noted, and added together; the sum of A and B is then to be divided by A, the first number noted. This number presents the weight of a bulk of water, equal in bulk to the coin; while the sum of the numbers, A and B is equal to the weight of the coin; since that aggregate we have been found equivalent to the weight of the coin in air. Let this weight be called C.

*Method of finding the Specific Gravity of a Body lighter than Water, by Nicholson's Gravimeter.*

598. Should the specific gravity of a light body, as a piece of cork for instance, be in question, place it on the upper scale of the gravimeter, load the instrument with weights, until the mark on the stem may coincide with the surface of the water, as in the above stated, a leaden disk being previously laid upon the lower scale. When the cork is removed, the weight requisite to compensate its absence, gives the weight of the cork. This weight, being added to that which will compensate its weight when immersed in water by being placed beneath the leaden disk in the lower scale, gives the weight of a quantity of water equal in bulk to the cork. Hence, the number of grains representing the weight of the cork be divided by that representing the weight of its bulk of water, the quotient will be the specific gravity, in this case, must be expressed in a decimal fraction, as it is less than unity.

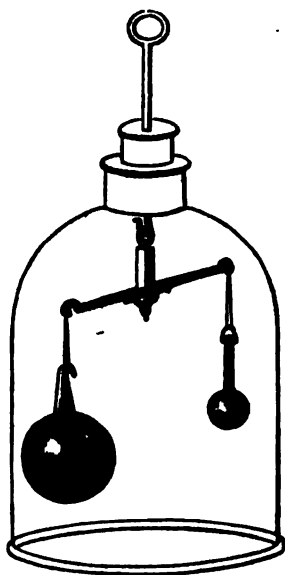
*Method of ascertaining the Specific Gravity of Gaseous Substances.*

599. Suppose the globe A, represented in the adjoining figure, to be removed from the receiver, R, and exhausted during a temporary attachment to an air-pump, by means of a screw with which the globe is furnished, and which serves also to fasten it to the receiver, as represented in the figure. Being preserved in this state of exhaustion by closing the cock, let it be suspended from a scale beam, and accurately counterpoised, as in a former experiment. (71, &c.) In that experiment, after the globe was counterpoised, air was admitted and caused it to preponderate decidedly. If in lieu of admitting air, the globe be restored to the situation in which it appears in this figure, so as to be filled with hydrogen from the receiver, R, and afterwards once more suspended from the beam, instead of preponderating decidedly as when air was allowed to enter, the additional weight acquired by it in consequence of the admission of the hydrogen, will scarcely be rendered perceptible. Supposing, however, that the additional weight

required were detected, and also the weight gained by the admission of the same bulk of atmospheric air, after a similar exhaustion of the globe, the weights of equal volumes of hydrogen and air would be represented by the weights thus ascertained. The specific gravity of atmospheric air is the unit, in multiples or fractions of which the specific gravities of gases are expressed. Hence the weight of a given bulk of hydrogen, divided by the weight of an equal bulk of air, gives the specific gravity of hydrogen. By a similar process, the specific gravity of any other gas may be ascertained.

*Of the Influence of the Air on the apparent Weight of Bodies.*

The most illustrious illustration of the loss of weight, and consequent inaccuracy attending the ordinary process of weighing, as conducted in the air, is afforded by the experiment described in the next page. (601, &c.)

*A Pound of Feathers heavier than a Pound of Lead.*

601. If two bodies, one of which is more than the other, be found equiponderant in ordinary process of weighing by a balance, the larger body is the heavier.

602. Let the bodies in question be those sent within the receiver of an air-pump, annexed figure. On withdrawing the means of the pump, it will be found the larger body preponderates, though previously counterpoised with accuracy.

603. *Rationale.*—It appears from a preceding narration, (573, &c.) that, when any body is surrounded by a fluid, it is buoyed up with a force in proportion to the weight of the fluid, and the quantity displaced by the body. Of course, the more it occupies in proportion to its weight, the more will its weight be counteracted. In the case of the two bodies rendered equiponderant in air, the weight of the larger is most counteracted by air. Hence, on exhausting the air from the receiver, the larger body shows a preponderance over the other, equivalent to the superior weight which the air had afforded it.

604. A similar result may be obtained, if hydrogen be substituted in the receiver for atmospheric air; because, as its specific gravity to that of air is only as 1 to 14 nearly, each body would lose 13-14ths of the support which the air had afforded it, but the larger body, having received more, would lose more. It follows, then, the common saying, that "a pound of feathers is as heavy as a pound of lead," is short of the truth; as they would really prove heavier were the air removed.

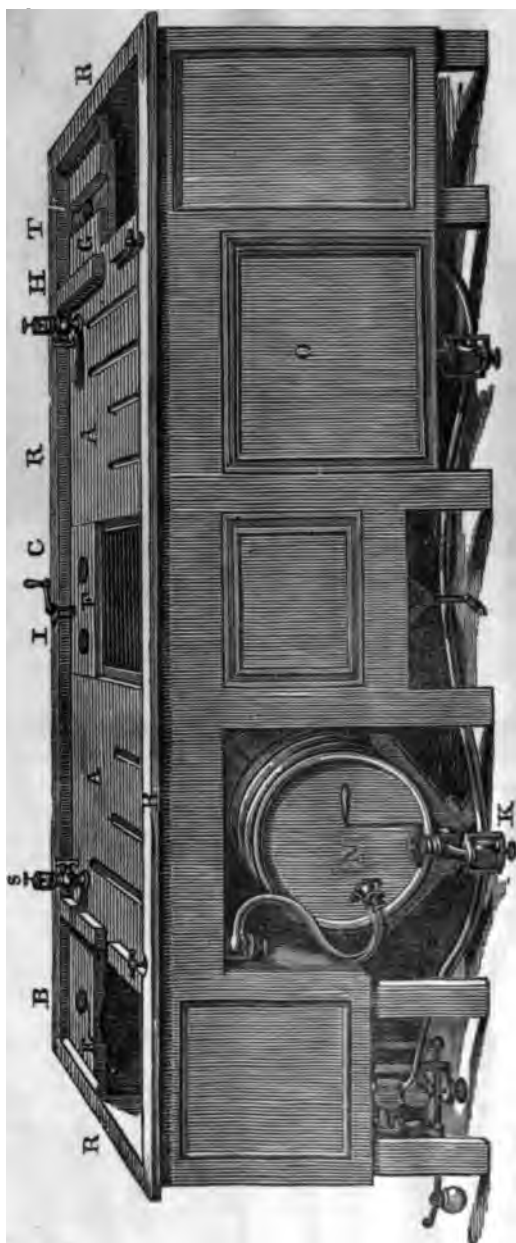
*Table of the Specific Gravities of the Principal Permanent Gases: also of the Liquids, of 100 Cubic Inches of each Gas.*

605. This table is inserted here for convenient reference, not as an object of collective.

	Specific gravity at 60 degrees.	Weight 100 cubic inches of each Gas.
Air	1	30
Oxygen	1.1111	33
Chlorine	2.5	75
Protoxide of chlorine	2.4444	73
Hydrogen	0.0694	2
Steam	0.625	19
Chlorohydric (muriatic) acid	1.28472	38
Nitrogen	0.9722	29
Nitrous oxide	1.5277	44
Nitric oxide	1.04166	31
Ammonia	0.59027	18
Sulphurous acid	2.2222	67
Sulphydric acid (sulphuretted hydrogen)	1.1805	35
Carbonic oxide	0.9722	29
Carbonic acid	1.5277	44
Carburetted hydrogen (light)	0.5555	17
Olefiant gas	0.9722	29
Cyanogen	1.8055	54
Chloroxycarbonic acid	3.4722	104
Fluosillicic acid	3.6111	110
Fluoboric acid	2.3692	71



*Hydro-Pneumatic Cistern.*





## SECTION IV.

DEFINITION AND DISCOVERY OF THE AERIFORM FLUIDS  
CALLED GASES.

606. It appears from the nature of calorific repulsion, that solid ponderable matter, by combining with caloric, first expands, next melts, and finally passes into that elastic state of fluidity, in which the repulsive power so far predominates over the attractive, that the particles recede from each other as far as external pressure will permit. When a substance is naturally aeriform, it is called a gas: when it retains the form of a solid only, in consequence of extraordinary (238,) heat, or removal of pressure, it is called a vapour.

607. All gases were considered as common air, variously modified by impurities, until Dr. Black ascertained the nature of carbonic acid gas. Incited by this discovery, oxygen, nitrogen, hydrogen, chlorine, and many other substances susceptible of the gaseous state, were discovered, or distinguished; by Scheele, Priestley, Cavendish, and others.

*Of the Art of Collecting and Preserving the Gases.*

608. Cisterns filled with water or mercury, called *hydro-pneumatic* or *mercurio-pneumatic* according to the liquid employed, are used for collecting gases. The vessels intended to contain the gas are filled with water or mercury, and placed, in an inverted position, on a shelf, or part of the cistern, situated just below the surface of the liquid. As their orifices are not raised above the surface, they remain full of the liquid, in consequence of the pressure of the atmosphere. (86, 87, 132.) Any gas emitted under the mouth of a vessel, so filled and situated, rises to the top and displaces the contained liquid.

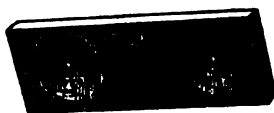
*Hydro-pneumatic Cistern.*

609. In the Appendix will be found an engraving and description of a hydro-pneumatic cistern, which I employed in the experimental illustrations of my lectures for more than ten years; and which I should probably continue to use now, had not the demand of water from the public works, put it into my power to dispense with the mechanism for keeping the water at a proper level. As I am now situated, any deficiency of water is easily supplied from the pipes known here as the hydrant pipes, by which the city is supplied with water; and any excess is carried off by a waste pipe. 610. A A, (see opposite engraving) is a water-tight platform, surrounded by a wooden wall, B B R R, rising above it about an inch and a half. B, C, T, are three wells or cisterns, each in the form of a hollow parallelepiped, with all of which the cavity bounded by the rim communicates; so that when supplied with water to the level of the waste pipe, this liquid fills the wells, and covers the platform to the depth of about  $\frac{1}{16}$  of an inch.

611. E, F, G, are shelves, which severally move in grooves over the wells, so that they may be placed in the most convenient position. Under H is a waste pipe. At

I, is a winch which serves to let in water from the public reservoirs. K, is a pipe for emptying the wells and casks, with all of which, by means of cocks, it may be made to communicate when requisite. N, is a cask which acts as a gas-holder, letting a communication with the cistern for letting in water from that source; the pipes being controlled by valves. By means of a pipe proceeding from its vertex, the gas-holder communicates with a pipe or cock, at a, furnished with a galloway screw. To this, flexible leaden pipes may be attached, for transferring gas either from a gas-holder to a bell glass, or from a bell glass to the gas-holder. When a communication is established between the cavities, either of these offices may be performed accordingly as the pressure within the holder is made greater or less than that of atmosphere. It will be greater when the valve for the admission of water is open, that for letting it out being shut; and less when these circumstances are reversed.

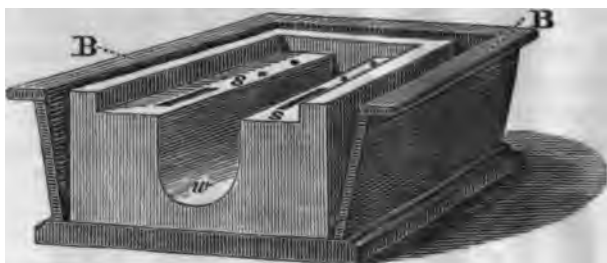
612. Another cask with pipes and cocks, similar to that represented in the engraving, is concealed by the panel, O.



613. This cut affords a view of the lower side of a sliding shelf, in the wood of which will be seen two excavations, T, T, converging into two holes. The shelf is loaded with an ingot of lead at L, to prevent it from floating in the water of the cistern.

#### *Mercurio-pneumatic Cistern.*

614. The following figure represents the mercurial cistern used in my laboratory. The front is supposed to be removed, that the inside may be exposed to view.



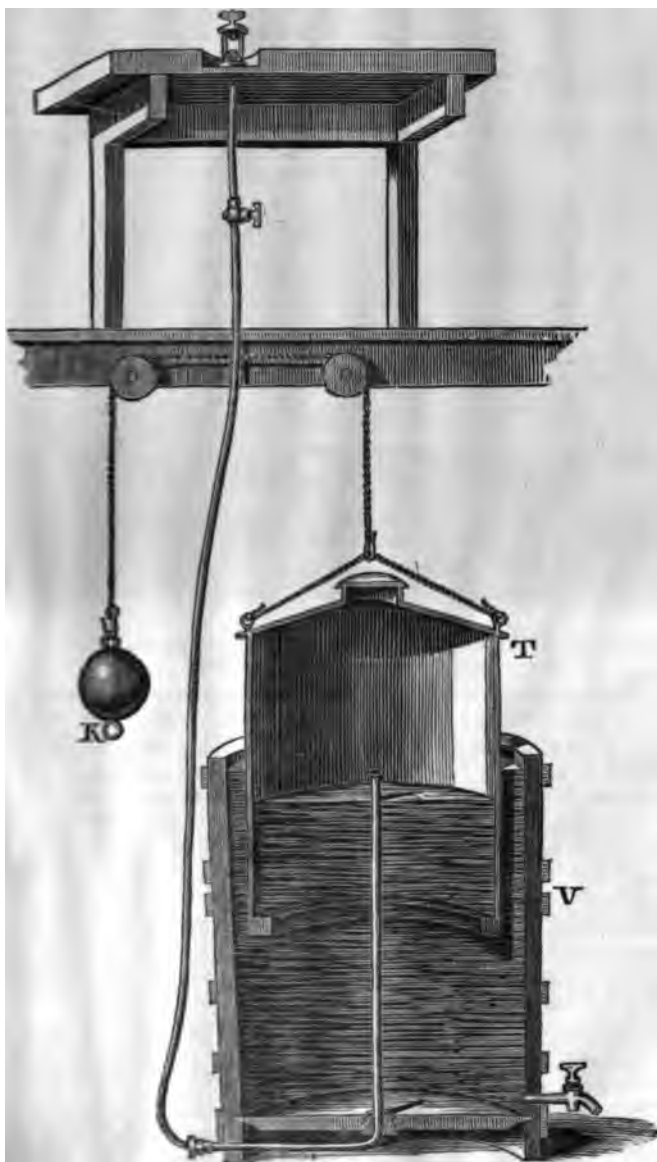
615. B B, is a wooden box, which encloses the reservoir so as to catch any of metal which may be propelled over the margin of the cistern. This box is bottomed upon stout pieces of scantling, tenanted together and grooved so as to conduct mercury towards one corner, where there is a spout to convey it into a vessel, adapted so as to receive it. The cistern itself is made out of a solid block of white marble. It is 27 inches long, 24 wide, and 10 deep.

616. The ledges, S S, answer for the same purposes as the shelves in the hydropneumatic cistern described in the preceding article. The excavation, w, constitutes the well. In this well vessels are filled with mercury, in order to be inverted and placed while full on the ledges. There are some round holes in the marble for introducing upright wires to hold tubes or eudiometers; also some oblong mortices allowing the ends of tubes, duly recurved, to be introduced under the edges of the ledges to be filled with gas, and in cases of rapid absorption, to afford a passage for mercury into vessels, into which its entrance might be impeded, in consequence of their close contact with the marble of the reservoir. To fill this reservoir requires nearly 600 pounds of mercury.

#### *Large Gasometer for Oxygen.*

617. The opposite engraving represents a section of my gasometer for oxygen and other gases, which is capable of holding between eight and nine cubic feet of gas. It is represented as it was situated, when the drawing was made, in the cellar of my lecture room. It is now placed in the lecture room in front of my table, at the other end. The wooden tub, V, is necessarily kept nearly full of water. The cylindrical vessel, T, of tinned iron, is inverted in the tub, and suspended and composed by the rope and weight, in such manner as to receive any gas which proceeds from the orifice of the pipe in its axis. This pipe, passing by means of a water-tight juncture through the bottom of the tub, is extended to a cock fixed

*Large Gasometer for Oxygen.*





cavity made in the plank forming the rim of the pneumatic cistern. Hence by means of this cock, and a leaden pipe soldered to a brass knob, properly perforated, a communication may be established between the cavity of the gasometer and any other vessel, for the purpose either of introducing or withdrawing gas. In filling this gasometer, the copper vessel and bell glass, used in obtaining nitrous oxide, may be employed advantageously; or the counter-weight being made heavier than the vessel, by appending additional weight to the ring, K, the gas may be sucked in from a bell glass, situated over the pneumatic cistern, as fast as it enters the bell from the generating apparatus.

61. As the gas displaces the water from the cavity of the vessel, T, the latter becomes more buoyant, and consequently rises. When any gas is withdrawn or expelled, the water resumes its place, and the vessel sinks.

62. Gasometers which contain 40 or 50,000 cubic feet have been constructed upon this principle for holding the gas from oil or coal. They are usually hollow parallel-pipeds. The upper vessel is generally made of varnished sheet iron, the lower one of brick work or cast iron. The space within the lower vessel, which is included by the upper one when down, is filled up, so as to lessen the quantity of water required. (See article on carburetted hydrogen.)



## INORGANIC CHEMISTRY,

### OR CHEMISTRY OF INORGANIC SUBSTANCES.

#### OF SIMPLE PONDERABLE ELEMENTS, THEIR REACTIONS WITH EACH OTHER, AND THE RESULTING COMBINATIONS.

63. Having in the preceding pages treated of certain general properties of ponderable matter, or those means of ascertaining or observing them of which a knowledge is indispensable to a chemist, I shall, in the next place, proceed to the consideration of ponderable substances individually, and their reactions and combinations with each other.

64. In treating of ponderable elements and their multifarious compounds, two arrangements have been pursued by different writers. Some have preferred to begin with elements, and to proceed to compounds; others to begin with compounds, and to proceed to elements. In favour of the last method, it may be alleged, that the most interesting substances in nature become known to us at first, in a state of combination. Thus, for instance, the air, water, salts, acids, alkalies, also flesh, sugar, farina, and other organic products, valuable either as food or as medicine, are compounds which have been naturally made the subjects of chemical inquiry; and it may be inferred that the student might with advantage be induced to travel in those paths, of which a successful pursuit has led to that chemical knowledge which is the object to impart. In this way he proceeds from facts which he knows, to such as he ought to learn, in the order in which he would spontaneously advance as far as he might be competent. But it may be observed, that no sooner are the ingredients of a body stated, than the student is distracted by names, of which he is ignorant; and which there is an immediate necessity to explain. Hence it follows that the ingredients of a compound may come to be considered in immediate succession, when they may have no analogy with each other; while it is highly advantageous, after having treated of any one element, to proceed to that which has the greatest analogy with it. In that case, a certain portion of the conceptions which have been formed respecting one element, may be extended to another, with little mental exertion, and without much additional pressure upon the memory.

622. The method first mentioned of treating of each elementary substance first, and afterwards of compounds, is objectionable, because it can be put into practice effectually. To treat of the chemical habitudes of one element, requires that we should speak of other elements, in connection with which, those habitudes are displayed, and respecting which a beginner is of course ignorant. In pursuing this course, each substance must be treated of imperfectly, or language and illustrations employed, which the student is unprepared to understand.

623. The course which I have chosen is as follows. I begin with the element which, of all ponderable matter, has the most important part assigned to it in nature; I mean oxygen. The history, state of existence in nature, means of procuring, and properties of this substance, so far as they can be rendered intelligible to a novice, are stated, or exemplified and explained. In the next place to oxygen, I present chlorine to attention, which has at least as much analogy with oxygen, as any other known element, and at the same time, an agent of high importance. Having treated separately of oxygen and chlorine, as far as may be expedient, the compounds which they form with each other, may, in the next place, to a certain extent, be treated of with advantage. Then, guided by analogy, bromine and iodine, though inferior in importance, may be successively treated of, and subsequently all the compounds which they can form, either with oxygen or chlorine, or with each other. This system will be followed in treating of the elements.

624. Pursuant to this method, little can be said of fluorine in the section appropriated to its consideration, since those elements with which its most interesting reactions take place, cannot consistently be made the objects of attention under that section.

625. Cyanogen is, in its properties, analogous to chlorine, bromine, and iodine, yet being composed of carbon and nitrogen, should not be the object of attention, until the pupil is prepared by a knowledge of its constituents. Besides, it comes in consistently under the general head of carbon, which, agreeably to my plan, as above explained, comprises the compounds of carbon with all substances previously treated of, among which is nitrogen.

626. Of the fifty-four simple elements universally recognised by chemists, a list, with their equivalent numbers and symbols, has already been given. (560, &c.)

627. Of these elements, *chlorine, bromine, iodine* and *fluorine* are classed by Berzelius under the name of *halogen bodies*, or generators of salts; *oxygen, sulphur, selenium, and tellurium* are classed together under the name of *amphigen bodies*, or both producers; meaning that they are productive both of acids and bases. To the elementary halogen bodies he adds the compound body cyanogen. I object to this classification, the word salt admits of no definition, reconcilable with the use which has been made of it by the distinguished author; and because, from facts and notions practically sanctioned by him, and chemists in general, it is evident that the elements belonging to both of his classes are productive of acids and bases. Hence I have associated them in one class, under the appellation of *basacigen elements*. In honour of Berzelius, I shall, however, retain the terms *halogen* and *amphigen*, in order to designate the elements which he has distinguished by those names. It may be proper to add we owe to Berzelius himself the idea that any other substance besides cyanogen could form acids and bases capable of uniting to form salts.

knowledge of the existence of this faculty in three of his amphigen elements, sulphur, selenium and tellurium, is, I believe, entirely due to his misapprehensions. If chemists, myself among others, who consider his double class as consisting of acids and bases, are in the right, it is to the light afforded by his brilliant discoveries that we owe the ability to pursue the true line.

185. Before concluding this preliminary exposition of the classification and nomenclature which I propose to adopt, I wish to make it clear, that the faculty of producing both acids and bases, which, agreeably to the view of Berzelius, is restricted to his four amphigen elements, is, agreeably to mine, extended to the elements comprised in both of his classes, and consequently united under one designation, as basacigen elements. My new class is, therefore, the amphigen class of Berzelius, enlarged and more descriptive name,\* so as to take in both of his gen and amphigen classes.

In order to render the definition of a basacigen body precise, it is necessary that I should give a definition of acidity and basidity.†

I shall proceed to give a definition which to me appears quite satisfactory. It is perhaps necessary to premise, that a *tertium quid* agreeably to the old chemists, a compound in which the qualities of the elements were neutralized, or so much altered, as to make a body of a chemical reaction differing from that of either of its ingredients. It is, therefore, a *third something*, a "*tertium quid*." But to proceed to the definition; it is as follows.

*When of two compounds capable of combining together to form a compound, and having an ingredient common to both, one prefers the other the negative pole of the voltaic series, we must deem the former an acid, the latter a base.‡*

Thus sulphuric acid, (consisting of sulphur in combination with oxygen and soda, (consisting of sodium and oxygen,) are capable of combining to form sulphate of soda, a *tertium quid*. Each of these compounds contains a common ingredient, oxygen, and one of them, the acid, prefers the positive pole of the voltaic series, the other the negative pole. It follows, that sulphuric acid is entitled to the appellation of an acid, while soda may be considered as a base.

It, I trust, be perceived, that a basacigen element is one capable of producing both an acid and a base, the monosyllable *gen* being understood, in chemical nomenclature, when added to a word expressive of a property, or state, to signify the production of that property, or state. (633.)

It is much needed to convey the idea of the basic property, as well as of the acid property, I have ventured, without any authority, to employ the word basidity, which from its analogy with acidity, must, I presume, be intelligible.

It is to be understood, that I consider this definition as only declaratory of the rule of chemists, who all obey the rule, although, as far as I know, excepting this, it has never been enunciated.

It seems it necessary to introduce into the text a corollary, which follows from the cited definition, as it would unnecessarily distract attention. It may be well before taking leave of this subject, to say, that agreeably to the practice, any body which is capable of saturating a base, is considered as an acid; and that on the other hand, any body which is capable of saturating an acid is considered to be a base. It is upon this basis that the pretensions of the ordines and acids to be considered as acids or bases, are founded.

## OF INDIVIDUAL PONDERABLE ELEMENTS, AND OF THEIR REACTION WITH EACH OTHER, AND THE RESULTING COMPOUNDS.

633. *Classification.*—Of the fifty-four elements enumerated, (627,) eight being designated as basacigen, make, with cyanogen, the compound basacigen body, (629,) nine in all in the basacigen class. I shall designate the rest of the elements as *radicals*; subdividing them into *metallic radicals*, and *non-metallic radicals*.

### OF BASACIGEN ELEMENTS.

634. Oxygen,	Cyanogen,
Chlorine,	Sulphur,
Bromine,	Selenium,
Iodine,	Tellurium.
Fluorine,	

They will be treated of in the order in which they have been named, in the eight following sections.

635. I have already stated that in honour of Berzelius should employ his appellations amphigen and halogen. There is, in fact, a necessity for words to distinguish the bodies to which he has applied these names; especially from the very great analogy between those which are designated as halogen.

636. The student is requested to recollect that chlorine, bromine, iodine, fluorine and cyanogen constitute the halogen class of Berzelius, while oxygen, sulphur, selenium and tellurium form his amphigen class.

### SECTION I.

#### OF OXYGEN.

637. In the gaseous state, oxygen forms one-fifth of the atmosphere in bulk; and as a constituent of water in the ratio of eight parts in nine, it pervades every part of the creation where that important compound is to be found. It exists in that congeries of oxidized matter which we call earth, and is a principal and universal constituent



and vegetable matter. Its combinations with metals and various other combustibles are of the highest importance in the arts. It was called oxygen under the false impression of its being the sole acidifying principle from the Greek *οξύς* acid, and *γενεσθαι* to generate.

*Preparation.*—It can only be isolated in the form of gas. It is yielded by red lead, nitre, or black oxide of manganese, when exposed to a bright red heat in an retort. There are various other means of obtaining oxygen gas. It is generally supposed that, in order to obtain it in a high degree of purity, chlorate of potash should be employed; but I have found the first portions of gas as evolved by a red heat from nitrate of potash or carbonate of soda very nearly pure; and Dr. Thomson alleges that this salt, by exposure to a carefully regulated heat, parts with one-fifth of the oxygen of its acid in a state of purity; or in other words, it gives up an atom of oxygen for every atom of the salt, which is equal to 8 in 102 parts, or rather more than one-thirteenth.

9. *Properties of Oxygen.*—The specific gravity of this atmospheric air being 1., is 1.1024. One hundred cubic inches of it weigh 34.1872 grains. In refracting light, oxygen is inferior in power to any of the other gases.

10. It is insipid, inodorous, colourless, and transparent. It is but slightly absorbed by water, does not differ from common air in appearance, but is somewhat heavier, and supports life and combustion more actively. Under a bell jar filled with oxygen gas, an animal lives, or a candle burns twice as long, as when similarly situated with the same quantity of common air. Oxygen gas is supposed to consist of oxygen rendered æriform by caloric. The equivalent of oxygen is 8, hydrogen being unity.

*Apparatus for obtaining Oxygen upon a large Scale.*

1. As nearly as much time and trouble are expended in conducting a chemical process on a small scale as upon a large one; and as in my experiments I consume large quantities of oxygen gas, I have lately employed the cast iron alembic represented in the following figure, for the purpose of obtaining the gas from 12 or 15 pounds of nitre. When in operation, it is made to occupy a suitable cavity in a furnace. The neck is so formed as to receive a large hollow knob of iron, from which a gun barrel proceeds at right angles. This knob is secured by a gallows screw, turning the arms cast with the alembic. The juncture is to be luted with a solid dry to a saturated solution of borax. To the orifice of the gun barrel, a leaden pipe is attached, by which the gas is conveyed to the gas-holders.

2. Care is taken to use no more fire than will bring over the gas, and the operation is arrested as soon as the impurity exceeds 20 per cent. By attending to these



precautions, the gas is of better quality; the first portion being nearly pure, and the alembic is less corroded. Besides, the nitrate, being converted into nitrite of potash produces, by deflagration with charcoal, a tolerably pure carbonate of potash.

### *Experimental Illustrations of the Properties of Oxygen Gas*

643. Several cylindrical glass vessels of an appropriate shape being filled with the gas over one of the shelves of the pneumatic apparatus, the following illustrations of the energy of oxygen gas in supporting combustion are afforded.

644. Let a stout wire be made, at one of its ends, to embrace a lighted candle, so that it may be conveniently lowered into the bell while replete with oxygen. It will be found that, if the flame be extinguished, and the candle lowered into the gas while the snuff remains red-hot, inflammation will be renewed with great energy.

645. The vessel being replenished with gas, the flame of a piece of burning caoutchouc, let down into it, acquires dazzling brightness.

646. Let Homberg's pyrophorus, or preferably such as have contrived to obtain from Prussian blue, or tannate of iron fall through the gas. During its descent the pyrophorus takes fire spontaneously, producing an igneous shower.

47. An analogous fiery shower results, when charcoal, or filings of iron or steel, made red-hot in a crucible, are projected in like manner into oxygen.

48. If (by means of a blowpipe,) a jet of oxygen be directed to act upon a lamp flame, or upon that of hydrogen, whether pure or carburetted, an intense heat will be exhibited. (379.)

49. An iron wire, being heated in the flame thus excited by oxygen, takes fire, and continues to burn splendidly, although the lamp be removed.

*Combustion of Iron or Steel in Oxygen.*

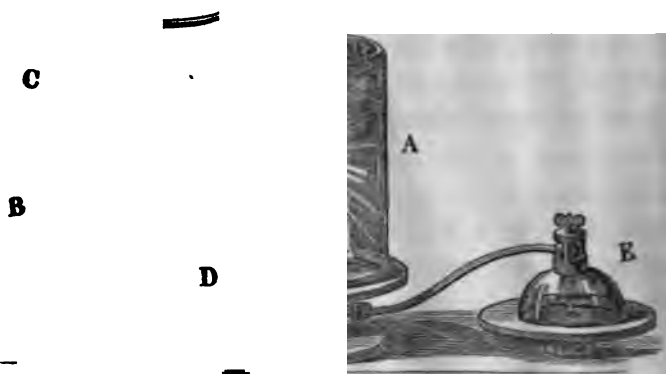


50. Place over the orifice of a pipe communicating with a cock of one of the air holders supplied with oxygen, a glass vessel, such as is usually employed to shelter candles from currents of air. Let the upper opening of the vessel be closed by a lid with a central circular aperture, as represented in the engraving. Leaving this aperture open, by turning the key of the cock, allow the gas to rise into the vessel, from the holder. Next apply a taper to the aperture, and as soon as it indicates, by an increased brilliancy of combustion, that oxygen has taken the place of the air previously in the vessel, cover the aperture. In the next place, attach a small piece of spunk to one end of a watch spring, or of a spiral wire as in the figure. Ignite the spunk, and removing the cover, plunge the end of the spring associated with the spunk into the gas. The access of the oxygen causes the spunk to be ignited so vividly, that the spring or wire, takes fire and burns with great splendour, forming a brilliant liquid globule, which scintillates beautifully. This globule is so intensely hot, that sometimes, on falling, it

immediately sink into the water, but leaps about on the surface, in consequence of the steam which it causes the water to emit. If it be thrown against the side of the containing vessel, it usually fuses it without causing a fracture, and has power to pass through the glass, producing a perforation without any other effect. These phenomena are more likely to be produced when an iron wire is employed in this experiment, than when a steel spring is employed, as the fusing point of iron is higher than that of steel.

*Necessity of Oxygen to a Candle Flame demonstrated.*

1. A candle will burn only for a limited time in a limited supply of air; it will not burn in vacuum, but burns brilliantly in oxygen gas, and much longer than in a quantity of air.



652. Let there be two bell glasses, A and B, communicating with each other by a flexible leaden pipe, a cock intervening at C. Suppose A to be placed over a lighted candle on the plate, D, which communicates with an air pump plate as represented at E. It will be found that the candle will gradually burn more dimly, and will last go out, if no supply of fresh air be allowed to enter the containing bell. In repeating the experiment, the air be withdrawn by means of the pump, the candle rapidly extinguished. It is thus demonstrated that a candle will not burn in *vacuo* and that it can burn only for a limited time, in a limited portion of atmospheric air.

653. If, while the bell, A, is exhausted, the cock at C be opened, communication with the receiver, B, filled with oxygen over the pneumatic cistern, the water rise into and fill the receiver, while the gas will be transferred to the bell. By means of the galvano-ignition apparatus (335), the candle may be again lighted, and it will burn splendidly.

*Combustion of Phosphorus in Oxygen Gas.*

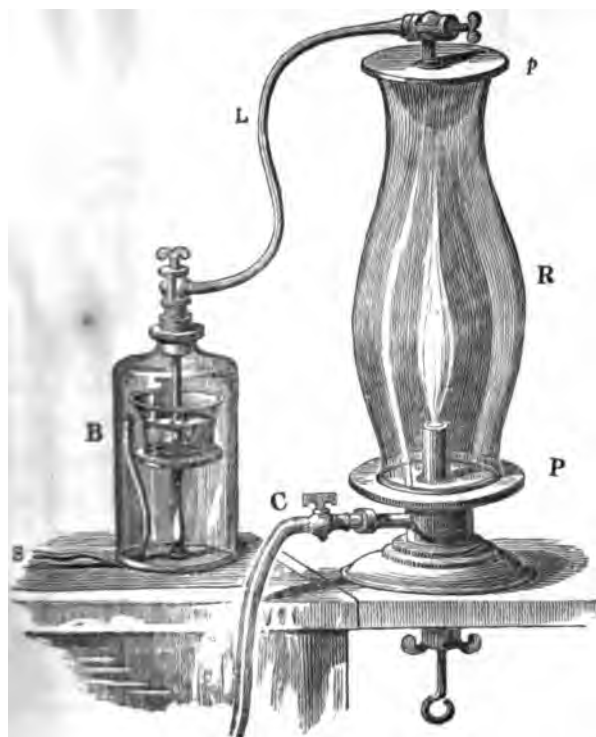


654. A brass plate, which answers as an extra air pump plate, is supported by a hollow cylinder of the same metal. Concentric with the axis of this cylinder

is through it, so as to reach about three inches above the plate, there is a coat three-fourths of an inch in diameter, open below, but closed above by a copper disk to which it is hard soldered. The tube is fastened into the top of a brass screw plug, in the centre of which the tube is soldered. Hence, the bore of the tube is accessible from below, so far up as the concave copper disk surmounts it, no air can pass through it, or through the cylinder. About twenty grains of phosphorus being placed upon the copper disk, a glass is put over it upon the plate; and by causing one of the pipes which are laterally to the cylinder to communicate with an air pump in operation, the air is exhausted. By means of the other pipe, a due quantity of oxygen gas is drawn from the bell glass, B, to which this pipe is annexed. The apparatus is prepared, the end of an iron rod previously reddened in the fire, is passed into the bore of the tube so as to touch the copper disk which holds the phosphorus. The most vivid ignition ensues. The light has at first a dazzling beauty, then "aborts of its beams" by the dense white fumes of phosphoric acid, which soon evolves. Hence, an effulgence, approaching to solar brilliancy, soon succeeds, a milder illumination like that of the moon, rendered more pleasing by the

the globes with which I am accustomed to perform this experiment contain gallons. It is better that the gas in the globe should be in some degree exhausted, otherwise the expansion at first excites a considerable effort in the air to resist the enlargement of bulk, arising from the heat, may be provided for by a siphon, a communication with which being opened, a portion of the heated gas is enabled to retire, till the condensation of the oxygen with the phosphorus, and phosphoric acid, compensates the expansion. I have performed this experiment, when the density of the gas was one-half of its equilibrium with the atmospheric pressure. This of course obviated the possibility of any ill consequences from expansion.

*Combustion of Sulphur in Oxygen Gas.*



658. Supposing the junctures made by the plates, P p, with the receiver, R, to be air-tight, and that there is a communication between it and the bell glass, B, means of a flexible leaden pipe, L, it must follow that, whenever the suction pump from which the recurved pipe, S, terminating within the bell, proceeds, is made act, the air in B being rarefied, that in R will force its way through L, and the lig in the vase upon the stand. It must also be evident that, if the pipe and cock, communicate, on one side with the receiver, on the other with a reservoir of oxygen, this gas will be impelled into the receiver, as soon as the cock is opened, in order to restore the equilibrium destroyed by the suction pump.

659. The plate, P, with its supporting hollow brass cylinder, has been already described in the preceding article. The tube, surmounted by the disk, used in the combustion of phosphorus, is removed, and its place a piece of a gun barrel is taken in like manner, fastened, so that the butt-end may occupy the axis of the cylinder. The touch-hole being closed, a perforation, similar in size, is drilled in the end of the barrel, at the point from which the jet of flame is represented as proceeding. A tuft of sulphur, some cotton wool is inserted into the touch-hole, and a tuft, thus made, is soaked in sulphuric acid. The gun barrel, during a tuft of sulphur, some cotton wool is inserted into the touch-hole, and a tuft, thus made, is soaked in sulphuric acid. The gun barrel, during a tuft of sulphur, some cotton wool is inserted into the touch-hole, and a tuft, thus made, is soaked in sulphuric acid. The gun barrel, during a tuft of sulphur, some cotton wool is inserted into the touch-hole, and a tuft, thus made, is soaked in sulphuric acid.

660. In consequence of the rarefaction of the air in the bell, B, by the suction pump, the fumes of the burning vaporized sulphur are drawn through the tube, the vase upon the stand, in which, consequently, a mixed solution of sulphuric and sulphurous acids is produced.

### *Additional Illustration of the Combustion of Sulphur in Oxygen.*

661. The preceding illustration has not for two or three years, been exhibited before my class, yet presuming it might not be uninteresting to some of the students, this work, I have not omitted it from this edition. Later I have resorted to the following method of exhibiting the combustion of sulphur in oxygen, as being easier, and yet sufficiently pleasing and instructive. All the steps of the process for the combustion of phosphorus in oxygen are performed, as already described (651, &c.) but in lieu of a stick of phosphorus, a tuft of asbestos soaked in melted sulphur, is placed upon the capsule, with a minute piece of phosphorus beneath it. The latter when heated by the incandescent iron takes fire, and consequently ignites the sulphur, with which the asbestos is imbued. The whiteness and dazzling brilliancy, the light afforded by the combustion of sulphur in oxygen is inferior to that evolved by phosphorus, when similarly situated; but this inferiority is compensated by the splendour of its characteristic purple hue.

## SECTION II.

## OF CHLORINE.

As a gas, chlorine exists only by artificial means; as an ingredient in marine salts, in the proportion of fifths, it constitutes nearly a fiftieth of the matter of the ocean, and is widely distributed throughout the atmosphere as well as the sea. It is also an ingredient in some of the most active agents used in chemistry or medicine. It was discovered by Scheele, and called by him dephlogisticated marine acid. It afterwards received the name of dephlogisticated muriatic acid, or oxymuriatic acid, from Lavoisier and the chemists who adopted his nomenclature, from the erroneous idea that it was composed of muriatic acid and oxygen. Its present name was given by Sir H. Davy from *χλωρος*, green, because its colour is greenish.

*Preparation.*—It is obtained by heating in a retort or tubic, of glass or lead, three parts of black oxide of manganese, with four parts of muriatic acid; or the same quantity of this oxide, with eight parts of common salt, four of sulphuric acid, and four parts of water.

1. Being a gas, chlorine must be received over the pneumatic cistern in bell glasses or bottles; the temperature of the water should be raised, by adding a portion of oil, so as to keep it boiling hot. As much of it is absorbed if it remains in contact with the water, I generally employ glass vessels with air-tight stopples, in order that they may be removed from the water as soon as filled. Berzelius alleges that if the water employed be saturated with salt, there is less absorption.

2. Jars or bottles may be filled with chlorine gas, by means of a tube or retort beak, as in fig. 1, of the following engraving, reaching from the generating vessel to the neck of that into which it is to be introduced. The air displaced by the chlorine, in consequence of its superior density, without any admixture ensuing adequate to interfere with the exhibition of its characteristic properties.

3. When substances which take fire in the gas are to be produced, it is expedient that a communication should be made with the inside of a bladder attached, as in the following figures, which represent apparatus, of which fig. 1 is used for the combustion of metallic powders, fig.

2 for that of phosphorus, introduced by means of the tube L.

Fig. 1.

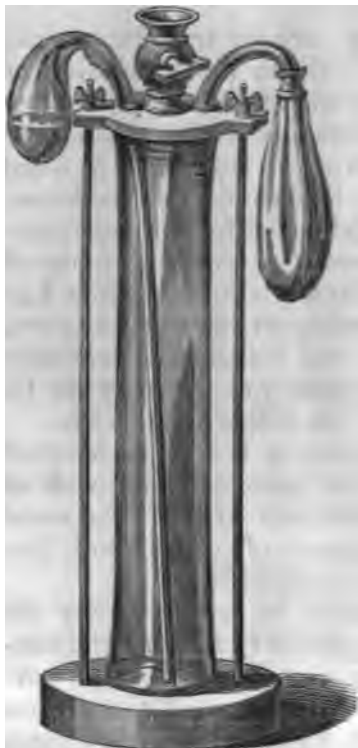


Fig. 2.



667. *Properties.*—When pure and dry, chlorine is a permanent gas of a greenish-yellow colour. Its weight that of common air, is nearly as two and a half to one. Even when existing in the air in very small proportions, it is intolerable to the organs of respiration, and to respire pure, would quickly produce fatal consequences.

668. Mr. Faraday has shown that, under great pressure, chlorine becomes a liquid. It will remain liquid some time after all pressure is removed, in consequence of the great cold produced by its evaporation.

669. That species of chemical action which is attended with the phenomena of combustion, is supported by chlorine gas with great energy. It combines directly with all combustibles except carbon. It has a curious property, noticed by me I believe, of exciting a sensation of warmth, though a thermometer, immersed in it at the same



not indicate that its temperature is greater than that of the adjoining medium. The heat thus noticed is probably produced by a reaction with the matter insensibly percolating.

0. Chlorine is absorbed by water, and the solution acts powerfully on metals. It appears to be the only solvent of gold. At the temperature of  $40^{\circ}$ , it forms with gold a solid hydrate, consisting of 1 atom of chlorine, 2 atoms of water. Silver, in solution, is the best test for chlorine; and, reciprocally, chlorine is the best test for dissolved silver. The compounds of chlorine with mercury are so useful in medicine, will be treated of when on the treatment of that metal. When the aqueous solution of chlorine is exposed to the solar rays, it forms muriatic acid with the hydrogen of the water, while the oxygen is liberated. It bleaches by liberating the oxygen of water, thus enabling it to act on the colouring matter. Although it has no direct reaction with oxygen, when in the nascent state, these elements unite to form four compounds, all of which are now considered as acids.

1. About thirty years ago, chlorine gas was universally considered as a compound of muriatic acid and oxygen, and called oxy-muriatic acid. It is now deemed an elementary substance, rendered gaseous by caloric.

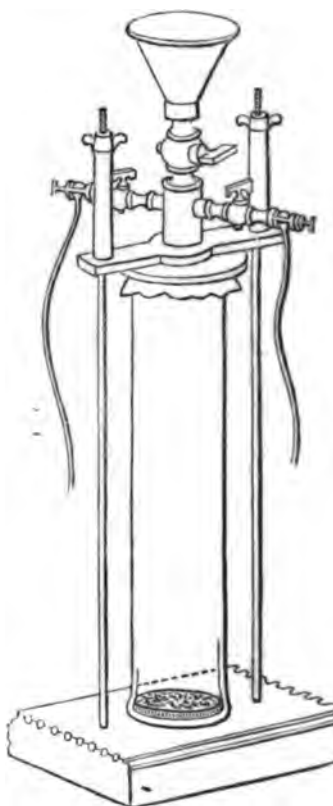
### *Experimental Illustrations of the Properties of Chlorine.*

1. Leaves of Dutch gold, introduced by means of a rod into a bottle of chlorine, take fire.
2. Calorific influence upon the fingers compared with upon a thermometer.
3. An infusion of litmus whitened in descending in a tube through the gas from a funnel.
4. A lighted candle introduced, burns with a carbonaceous flame.

#### *Combustion of Antimony in Chlorine.*

When an air pump is at hand, the following apparatus may be used for the combustion of powdered antimony. It consists of a large jar closed air-tight, and provided with the screw rod and plate frame described. (24<sup>th</sup>) By means of one of the flexible pipes and cocks with which the apparatus is furnished, communication may be made with an air pump, and with a large vessel containing chlorine. Into the centre of the lid a cock is fastened, the key of which instead of being perforated as usual, is drilled only half through, so as to produce a narrow orifice capable of holding a thimbleful of powder. The cavity in the lid of the jar is charged with pulverized antimony, which, on turning the key half round, falls through the chlorine, and as it falls assumes the appearance of a shower

of fire. The cock being, from its construction, always closed, and the being tight, the spectators are protected from the noxious fumes.



678. In this experiment, the chlorine forms with the antimony a compound has less capacity for caloric and light than its ingredients have separately. by their combination, the phenomena of combustion are produced. The combustion is the perchloride.

*Apparatus for the Combustion of Metallic Leaf\* in Chlorine.*

679. The apparatus used in this experiment (See fig. 1,) differs but little one above represented, (677, &c.) being the same as that described in (241, &c.) excepting the funnel, which is unnecessary in this case.

680. Into the lower end of the cock a rod of iron is screwed fast. This such dimensions as to extend from the top to the bottom of the receiver, a ported within it, so as to be in its axis or every where equidistant from the Before fastening the plate into the situation in which it is represented in it must be lifted in order to attach the leaf metal to the rod with the arabic. The arrangements being so far completed, the cylindrical receiver been exhausted by means of the air pump, the cock, regulating the communication with that instrument, is to be closed, and the other which controls the entrance of the gas is to be opened. By these means the leaves burn splendidly, being newly enveloped in an atmosphere of chlorine, which rushes in to supply the vacuum caused by the air pump.

---

\* The metal usually employed is the Dutch gold leaf of the shops, and principally of copper and zinc.

681. Another method of performing this experiment is illustrated by fig. 2.

FIG. 1.

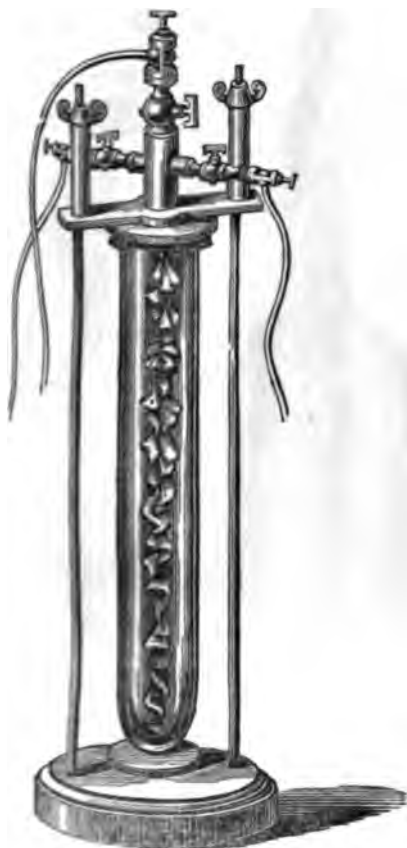


FIG. 2.



682. The metallic leaves being suspended from the plate which closes the bell, B, and this bell being exhausted of air by means of the pump, chlorine is suddenly admitted into A by the glass cock from the bell glass, A, previously supplied with gas.

*Spontaneous Combustion of Phosphorus in Chlorine.*

683. The figure at the top of the next page, is intended to convey an idea of the stupendous inflammation of phosphorus in chlorine, by means of an apparatus which enables the lecturer to perform the experiment without exposing spectators to the risk. Let there be a cylindrical glass vessel, eight or nine inches in diameter, about a foot in height, with a neck about four inches high, and one and a half inches in bore; the whole resembling a large decanter without a bottom. At the orifice of the neck, let there be cemented, air-tight, a brass cap, surmounted by a stuffing box, and having on one side a hole communicating with the cavity of the neck. This aperture must be furnished with a screw, by which it may be opened or closed at pleasure. Through the stuffing box a copper rod passes, the lower end of which a glass or leaden stopple is so affixed, as to close the lower part of the neck, into which it is ground to fit air-tight. Over this stopple, a cup is soldered, so as to be concentric with the rod. The rod terminates above the handle. Within the cup, let ten or fifteen grains of phosphorus be placed. This is easily effected when the cup and plug are depressed into the lower part of



the cavity of the vessel, by a suitable movement of the sliding rod. In this place draw up the cup and plug into the neck, so as nearly but not entirely to stop it, and sink the vessel into the water of the pneumatic cistern until all the air in the neck is expelled through the hole in the side of it, which is then to be closed by means of the screw, and the plug twisted and drawn into its place, so as to be tight. After filling the body of the vessel thus with water, place it upon the surface of the cistern. Chlorine may now be allowed to occupy three-fourths of the space within the vessel below the plug. The process being so far advanced, it is necessary, at the moment when it is desirable to produce the combustion, to draw up the plug, and of course the cup associated with it containing the phosphorus, the cavity supplied with the chlorine. The phosphorus soon burns actively, attended with a feeble light. The increased temperature consequent to the combustion causes the gas to expand, but not so much as to become too bulky to be retained in the vessel.

664. In this case the chlorine forms a chloride of phosphorus, which, mixed with water, is decomposed into phosphoric and muriatic acids. By transferring the products after it is supplied with chlorine, to a clean porcelain or glass dish, covered with pure water, the products of this combustion might be saved, and would of course increase in proportion to the quantity of phosphorus and chlorine employed. On a larger scale, this process might be resorted to advantageously for the preparation of phosphoric acid, which is produced when the proportion of chlorine is sufficient for four cubic inches for every grain of phosphorus.

*Of the Compounds of Chlorine with Oxygen, and of the Nomenclature of these Compounds and others formed with the Basicigen Class*

665. Consistently with the French nomenclature, the combinations of oxygen, chlorine, bromine, iodine, and fluorine, with other elements have been distinguished as *acids*, or characterized by a terminus "*ide*," or in "*ure*," which last monosyllable, when there has been intention of altering the meaning, has, by the British chemists, been tra-

into *uret*. The termination in *ide*, which is common to both languages, is, by *Thénard*, and other eminent French authors, restricted to the binary compounds of oxygen which are not acid. Analogous compounds formed with the *halogen* elements, chlorine, bromine, iodine, fluorine, cyanogen, &c., have by the same writer been designated by the termination in *ure*. Thus we have in his work, chlorures, bromures, iodures, fluorures, and cyanures. Some of the most eminent chemists in Great Britain have distinguished the elements called halogen by *Berzelius*, together with oxygen, as supporters of combustion, and have designated the binary compounds made with them, when not acid, by the same termination as the analogous compounds of oxygen. Accordingly, in their writings, instead of the names above mentioned, we have chlorides, bromides, iodides, fluorides. In *Henry's Chemistry*, cyanure is represented by cyanide; in *Thomson's*, by cyanide; and in *Brande's* and *Turner's*, by cyanuret. I shall follow the practice of the British chemists in the case of the four first mentioned compounds, extending it to the compounds of cyanogen, as *Henry* has done.

686. These rules of nomenclature will be considered as extending to all the *halogen* class. Of course, the compounds of sulphur, selenium and tellurium, when not acid, will be designated by appellations terminating in *ide*. In lieu, therefore, of *sulphuret*, *selenuret* and *telluret*, I shall in common with *Berzelius*, employ the words *sulphide*, *selenide* and *telluride*.

#### COMPOUNDS OF CHLORINE WITH OXYGEN.

687. 1 atom or 1 volume of chlorine equivalent 36. forms	{	With 1 atom, or $\frac{1}{2}$ volume of oxygen, or hypochlorous acid, . . . . .	44
		With 4 atoms, or 2 volumes of oxygen, chlorous acid, . . . . .	68
		With 5 atoms, or $2\frac{1}{2}$ volumes of oxygen, chloric acid . . . . .	76
		With 7 atoms, or $3\frac{1}{2}$ volumes of oxygen, perchloric, or oxychloric acid, . . . . .	92

#### Of Hypochlorous Acid.

688. This compound, of which the ingredients are stated above, (687,) is generated by the reaction of chlorine, with an excess of finely pulverized protoxide of mercury, suspended in pure water by agitation.

689. By these means, the chlorine, agreeably to the 4th case of affinity, (523. &c.) combines with both the oxygen and mercury, forming two compounds, a bichloride of mercury, and a protoxide of chlorine, or hypochlorous acid, which dissolves in the water. The bichloride combines with a portion of the undecomposed bioxide, and forms a kind of combination, generally designated as oxychloride, indicating that a substance so called consists of an oxide, and a chloride. The oxychloride formed in this case, being almost insoluble, is separated by filtration. A more concentrated solution of the acid is procured by successive distillations, in which as little heat as possible should be used, and preferably it should be accomplished by diminished pressure.\*

690. *Properties of Hypochlorous Acid.*—The aqueous solution of hypochlorous acid, resulting from the above described process, is, when concentrated, in colour slightly yellow, with an odour strong and penetrating,

\* For the purpose of distillation, by reduced pressure, the apparatus represented and described in page 69, (395.) might be used, substituting a second and third re-  
tort, well refrigerated, for the vessel, B, and the bottle, C. (188.)

resembling that of chlorine, but yet differing therefrom perceptibly; upon the skin its effects are similar to those of nitric acid, but more active. Its bleaching powers are eminently great. It is so much prone to decomposition, as to undergo that process spontaneously at ordinary temperatures, being resolved into chlorine and chloric acid. This change is accelerated by light, and ensues immediately from direct exposure to the solar rays. Bodies full of sharp corners, (the fragments of powdered glass, for instance,) when thrown into the liquid acid, are productive of an evolution of chlorine with brisk effervescence. The oxydizing powers of this reagent are powerful but various, being most active with non-metallic elementary radicals, such as sulphur, phosphorus, and selenium. Each of these it readily saturates with oxygen, and likewise iodine, and bromine, which are thus severally converted into bromic and iodic acid. Its reaction with gold and platinum, is but feeble, but with iron and silver energetic. The former is converted into an oxide, the latter into a chloride, while in the case of the one, the oxygen escapes, in that of the other the chlorine. Mercury it converts into an oxide, and a chloride, which form an oxychloride, by uniting in their nascent state.

#### *Of Gaseous Hypochlorous Acid.*

691. Balard, to whom we are indebted for our knowledge of the facts above stated, was successful in procuring hypochlorous acid in the gaseous form, by introducing into a concentrated aqueous solution over mercury, anhydrous nitrate of lime in successive portions. By its superior affinity for water, the nitrate causes the evolution of the acid in the æriform state, the mercury being protected by the interposed solution of the nitrate.

692. *Properties of Gaseous Hypochlorous Acid.*—The gaseous hypochlorous acid much resembles chlorine, in possessing a greenish yellow colour. Water absorbs 100 times its own volume of it.

693. A slight increase of temperature is sufficient to cause hypochlorous acid to detonate, and though less explosive than chlorous acid, it is apt to explode, when an effort is made to transfer it from one bell glass to another.

694. Its composition was ascertained by Balard, by analyzing the gaseous product resulting from its explosion, by which it was found to consist of one volume of chlorine, and half a volume of oxygen, as already stated. (638.)

#### *Of Euchlorine or Impure Chlorous Acid.*

695. In the last edition of this work, euchlorine was treated as a protoxide of chlorine, but it was, at the same time mentioned, that doubts existed whether the gaseous substance known by this appellation, might not be a mixture of chlorous acid with chlorine. These doubts appear to have been succeeded by an affirmative conviction, and accordingly I have omitted the name from the list above given, of the definite compounds of chlorine with oxygen.

696. Euchlorine is obtained by heating gently, in a small glass retort, equal parts of strong muriatic acid, water, and chlorate of potash. The retort should only be subjected to the flame of a small spirit lamp, or an inflamed jet of hydrogen, which should be so situated as not to heat the body of the retort above the part containing the liquid; as this may cause an explosion. It is advantageous to interpose, as a support for the retort, a plate of tin, having a circular aperture of about an inch and a half in diameter. By these means, the application of the heat may be sufficiently restricted.

697. The gas may be received over mercury, although not without inconvenience; since by its decomposition, in consequence of the large proportion of free chlorine with which it is associated, the mercury is superficially converted into a subchloride. But, while the covering thus formed, protects the surface of the metal from further erosion, it also, by coating the internal surface of the glass, hides, more or less, the remarkably deep greenish-yellow colour of the gas from the eye of the spectator.

698. Agreeably to Soubieran, when the gas thus obtained is passed through a tube, replete with protochloride of mercury, (calomel,) this chloride absorbs an additional atom of chlorine, and thus brings the chlorides acid to a state of purity. The rationale of the evolution of the mixture known as euchlorine, seems to be as follows. By double elective affinity, there is a reciprocal decomposition of the potassa and chlorohydric acid, causing the separation of the chloric acid, containing five atoms of oxygen. Consequently, by the reaction with these atoms, a further dehydrogenation of chlorine ensues, causing a portion to be set free, while another portion retains enough oxygen to constitute chlorous acid.

#### *Process for elaborating pure Chlorous Acid directly.*

699. Pure chlorous acid is obtained by distilling one part of chlorate of potash, fused into a mass, at the bottom of a small glass retort, with about  $3\frac{1}{2}$  parts of concentrated sulphuric acid, and receiving the gaseous product over mercury. The evolution of the gas takes place without heat at first, but to be completed requires a temperature near to  $140^{\circ}$ . This should not be exceeded, and the heat should be restricted to the bottom of the retort, as in the case of euchlorine. The process is replete with danger, as from slight causes this gas explodes with surprising force.

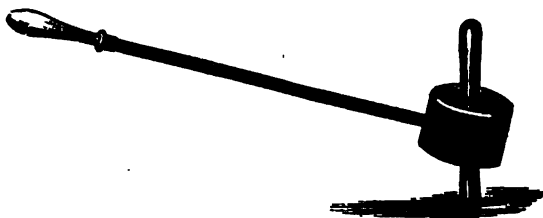
700. *Rationale.*—By the action of sulphuric acid on chlorate of potash, two compounds are produced, chlorous and oxychloric acid. The former is evolved in the gaseous state, the latter remains in union with the potash. It would seem as if one portion of the chloric acid were displaced from its union with the potash by the superior affinity of the sulphuric acid, and transferred a part of its oxygen to another portion of the same acid, so in union with the alkali. The chlorate of potash is thus partially converted into an oxychlorate. The deoxidized chloric acid constitutes a compound which is designated by Berzelius as chlorous acid. By others, it has been variously designated as the tritoxide, quadroxide, or peroxide of chlorine, in consonance with the different impressions entertained of its properties, or composition.

#### *Properties of pure Chlorous Acid.*

701. Chlorous acid gas has a yellow colour, which is deeper than that of chlorine. Its odour is somewhat aromatic, and bears no resemblance to that of chlorine. It whitens a solution of litmus, without reddening it. When subjected to an electric spark, or to a temperature of  $212^{\circ}$ , it explodes with great violence, giving out light and heat, and being converted into chlorine and oxygen. Agitating the gas with mercury will sometimes produce the same result. Water absorbs seven times its volume of chlorous acid gas, acquiring a deep yellow colour, and a peculiar acrid taste, which is nevertheless not at all acid. The aqueous solution, when added in small quantities, possesses the power of reddening litmus, and when exposed directly to the sun's rays evolves chlorine, while oxychloric acid remains in solution. In a diffuse light it takes several weeks to effect this decomposition, and it does not take place at all in the dark. Faraday has found

that chlorous acid gas may be liquefied by subjecting it to great pressure. The resulting liquid is of a yellow colour.

*A convenient and safe Method of effecting the Explosion of Euchlorine.*



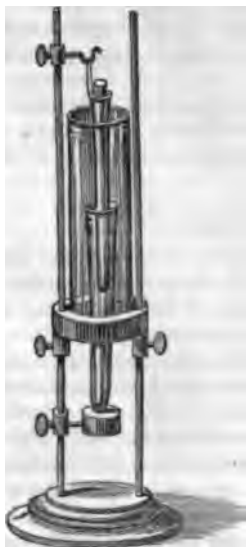
702. A convenient and safe method of effecting the explosion of euchlorine is represented in the preceding figure. The gas being introduced into a tube of about  $\frac{5}{16}$ ths of an inch in diameter, and fifteen inches in length, over mercury applying a heated metallic ring, an explosion ensues. The gas at the same time loses its greenish-yellow colour, and increases in bulk. The chlorine is subsequently absorbed by the mercury.

703. Thenard advises the application of a spirit lamp to produce the necessary temperature. It is easier and more safe to use the hot ring. The tube is of safety supported by an iron wire, which has been overlooked in sketching the figure.

704. *Rationale.*—Agreeably to the idea that aëriiform fluids owe their repulsive power to caloric, there ought, after an evolution of heat, to be a reduction of volume in any gaseous compound; but by the decomposition of euchlorine, although it is evolved with explosive violence, the volume of the gaseous matter is increased.

705. The only explanation which I can give, is, that the capacity for caloric in this case, as in others, is greater than the sum of the capacities of the constituents. Why the capacity of the compound should be greater, and why caloric should be more forcibly attracted by an atom of oxygen and an atom of chlorine when united than when separate, I cannot explain. This and other anomalies are no doubt connected with those of electricity, galvanism, and magnetism.

*Apparatus for exhibiting safely the Explosion of Chlorous Acid.*



706. The adjoining figure represents an apparatus for exhibiting, without danger to the spectators, the detonation of chlorous acid.

707. Into a tube of nearly  $\frac{5}{16}$ ths of an inch in diameter, and sealed at one end, about as much of potash is introduced as will rise above the surface about one inch. The mass thus situated is fused by means of a spirit lamp, or chauffer.

708. The tube, being then charged with a proper proportion of sulphuric acid, is corked gently and suspended within a stout glass cylinder, as shown in the drawing. It is then surrounded, near the bottom, by another tube, supplied with boiling water. As the hot water is applied only to that part of the inner tube which contains the salt; but as soon as the tube is pervaded by a greenish-yellow color, demonstrating the evolution of the chlorous acid, the outer tube containing the water is to be raised so that the gas may be generally heated by it; an explosion soon follows, from the influence of which spectators are protected by the glass cylinder.

*Preparation of Chloric Acid.*

709. When a solution of potassa (or potassium) or the carbonate of this alkali



impregnated copiously with chlorine, crystals precipitate, which consist of chloric acid in union with potassa. If to a solution of the chlorate of potash thus formed, fluohydrosilicic acid be added, an almost insoluble fluoride of potassium precipitates. From this an aqueous dilute solution of the desired acid may be obtained by filtration.

710. If, in lieu of a solution of potassa, water holding baryta suspended, impregnated with chlorine, a chlorate of baryta may be procured, from which the baryta may be precipitated by employing, as nearly as possible, an equivalent of sulphuric acid. It was by this process that Chenevix covered chloric acid; but it is alleged that when thus procured, it retains minute proportion of sulphuric acid.

711. *Properties.*—Chloric acid, thus procured, is inodorous, colourless, and astringent. It does not precipitate solutions of lead, mercury, or barytes, which, for a great majority of the compounds of chlorine, are infallible tests. When concentrated by evaporation, at a gentle heat, it is reduced to an oleaginous consistency, and acquiring a yellowish tint, also an odor like that of nitric acid. In this state it ignites paper, and other organic products, and is capable of converting alcohol into acetic acid. It is decomposed by many substances having an affinity for oxygen; and yet, in acting upon iron or zinc, is said to cause the oxidization of these metals, not, like nitric acid, at its own expense, but by the decomposition of water, of which the hydrogen is in consequence evolved. Many bodies which do not otherwise react with it, cause its decomposition when aided by the solar rays.

#### *Of Oxychloric or Perchloric Acid.*

712. *Preparation.*—After the chlorous acid has been liberated from chlorate of potash, the residue consists partially of oxychlorate of potash, as already stated. (700.) This is mingled with bisulphate of potash formed at the same time, but may be separated by repeated solution and crystallization, as the bisulphate is more soluble.\*

713. Oxychloric acid may be obtained from oxychlorate of potash by distillation in a retort with its own weight of sulphuric acid, diluted with a like weight of water at the temperature of  $280^{\circ}$ . It is purified by carefully precipitating the sulphuric acid which comes over with it, by means of barytic water, and redistillation.

714. *Properties.*—Like chloric acid, it is insusceptible of the gaseous form, and, as a liquid, exists only in combination with water, being limpid, colourless, and having a lively acid taste. It reddens, but does not subse-

\* In evolving oxygen from chlorate of potassa, by means of a porcelain retort and chamber of coals, it excited surprise, that while the greater part of the gas could be obtained in a glass retort, without softening the glass, there was a portion which required a higher temperature than that which flint glass is capable of enduring. While contemplating some experiments for the explanation of these phenomena, I learned that Soubeiran had furnished the true explanation of the mystery. He had maintained that one portion of the salt, receiving two equivalents of oxygen from another, became converted into an oxychlorate, of which the decomposition was more difficult than that of the chlorate. Subsequently this process has been resorted to by my young friend and late pupil, Mr. Boyé, and my son, to obtain oxychlorate, for which purpose they have subjected a pound of chlorate of potash, at a time, to partial decomposition. The mass which remains after all the oxygen has been expelled, that can be extricated without softening flint glass, consists of a mixture of chlorate of potassium and of oxychlorate of potash. As of all the salts of potassa, that in question is the most sparingly soluble in water at  $60^{\circ}$ , by solution in this liquid while boiling hot, and cooling the solution, the salt precipitates, and may be purified by repeating this part of the process.

quently bleach an infusion of litmus. It is decomposed by the solar rays, sulphurous acid, nor sulphuretted hydrogen. It dissolves zinc and iron with disengagement of hydrogen. It exercises strong affinities, and is the most enduring of the combinations of chlorine with oxygen; which is the more surprising, as it is in general true that in proportion as any one ingredient predominates in a compound, it is the more easily separated in part.

715. By the reaction of sulphovinic acid, with oxychlorate of barytes, Mr. Boyé and my son have procured an ether, which in its explosive energy, is scarcely equalled by the chloride of nitrogen. It is I believe the only *ethereal* compound which is *per se* explosive, or which detonates from a mechanical shock.



### SECTION III.

#### OF BROMINE.

716. This name has been given to a substance analogous to chlorine, from the Greek *βρῶμας*, fetidity.

717. Bromine was discovered by Balard in 1826, at the salt works of Montpellier in France, in the mother waters of marine salt, in the state of bromide of sodium or magnesium. Since then it has been found in the water of the Dead Sea, and in the greater part of the salt springs of the continent, especially those of Germany. In those of Theodorshalle near Kreuznach, a sufficient quantity has been found, to make it profitable to effect its extraction. Common salt, in its natural state, often contains traces of the bromides of sodium or magnesium.

718. *Preparation*.—The mother water of marine, or common salt, is impregnated with chlorine, until it acquires a hyacinth-red tinge. The chlorine combines with the hydrogen and magnesium of a bromide of magnesium, which exists in that water. The bromine, thus displaced, mingles with the water, which is to be washed with ether. The resulting ethereal solution of bromine, being treated with potash, a bromide of potassium is produced, which, heated in a retort with diluted sulphuric acid and manganese, yields bromine, as chlorine is obtained from a chloride by like treatment.

719. *Properties*.—Bromine is a liquid, but is so volatile, that a single drop is sufficient to fill a flask with its reddish-brown vapour. The specific gravity of bromine is 2.966, being nearly three times the weight of its bulk of water. It freezes at a temperature of from 7° to 12° below zero.

It has, when frozen, a crystalline and leafy texture, with a lead-gray colour, and a lustre almost metallic. It boils at the temperature nearly of  $89^{\circ}$ , forming a vapour resembling that of nitrous acid, and more than five times as heavy as atmospheric air. It does not conduct electricity. Flame is extinguished in the vapour of bromine, acquiring a greenish colour previous to its extinction. Bromine is slightly soluble in water. Its solubility is not sensibly augmented by heat. The solution has an orange colour, and emits red fumes. In alcohol it is more soluble, than in water, and in ether still more so than in alcohol.

720. It acts upon vegetable colouring matter and organic products, like chlorine, in general, decomposing them in consequence of its affinity for hydrogen. Bromine forms with starch, a yellow compound. It corrodes the skin, imparting a yellow tinge, which endures till the skin is renovated. In its habitudes with oxygen, hydrogen, sulphur, and phosphorus, and the metals, it has a great analogy with chlorine, but generally its affinities are not so strong. From its reaction with potassium, an intense and almost explosive combustion is said to ensue. When taken internally, bromine acts as a virulent poison.

721. Bromine is supposed to be one of the active substances in mineral springs, especially in those which contain common salt. By means of nitric acid it may be obtained in the form of a deep brown precipitate, from the mother waters in which it exists, but there is much lost by its solution, and subsequent volatilization during the evaporation of the solvent.

### *Experimental Illustration.*

722. Bromine exhibited as a liquid; also in the state of vapour.

### COMPOUNDS OF BROMINE WITH OXYGEN AND CHLORINE.

#### *Of Bromic Acid.*

723. Bromine forms but one compound with oxygen, called bromic acid, which was discovered by Balard.

724. *Preparation.*—When sulphuric acid is added to bromate of baryta dissolved in water, a sulphate of baryta is precipitated, and bromic acid remains in solution, which may afterwards be concentrated by evaporation.

725. *Properties.*—Bromic acid, thus obtained, is a liquid of the consist-

of sy we e portion of the  
 into oxy and bromine. Bromic acid  
 It has a strong taste, acid but  
 Sulphurous and phospho  
 gen for their radical, decompos  
 sulphuric acid produces the  
 ch bromic acid cannot exist.  
 atom of bromine 78, and five  
 re 118.

### Of Chloride Bromine.

727. When a current of chlorine is passed through bromine, a liquid compound is produced of a reddish-yellow colour, but not so deep as that of bromine. This liquid is volatile, of an intolerable smell, producing taste has an excessively disagreeable taste, and a colour resembling that of chlorine. Water dissolves this chloride, acquiring the power of bleaching litmus. Bases produce with its ingredients, a bromate, a bromide, and chloride.

## SECTION IV.

### OF IODINE.

728. Iodine has been found in various sea plants, especially the common sponge, also in mineral waters in a variety of regions of the earth, remote from each other. It exists also in combination with various fossils. From the experiments of my late friend Dr. Steel, of Saratoga, and others, it appears to be an ingredient in some of the mineral waters of that place.

729. *Preparation.*—Iodine is obtained from the lixivium of kelp, from which carbonate of soda is manufactured. After all the soda has been crystallized, the residuum is concentrated, and being heated with sulphuric acid, in a retort, the iodine passes over, and condenses in shining crystals of an intense purple or black colour.

730. Iodine may be precipitated from the mother water of salts, with which it is naturally associated, by a mixture of eight parts of sulphate of copper, and one of green sulphate of iron. From this precipitate iodine may be obtained by intense ignition, in a retort, with an equal quantity of dry peroxide of manganese.

731. *Properties.*—When solid, iodine is of a bluish-black colour, friable, and almost insoluble. It stains the skin yellow. It fuses at  $225^{\circ}$  and volatilizes at  $350^{\circ}$ , in a beautiful

vapour. Hence its name, from the Greek *ἰώδης*, violet-red. Its taste is acrid and hot, and continues for a time in the mouth. When taken internally, it acts as a poison. It is incombustible either in oxygen, or atmospheric air; but forms acids severally with oxygen, chlorine and hydrogen, called iodic, chloriodic and iodohydric\*.

In its habitudes with the Voltaic pile, it is more o-negative than any other matter, excepting oxygen, air, chlorine, bromine, and probably fluorine. With the varieties of fecula, starch, sago, arrow root, &c., it produces an intensely blue colour; so that these substances are reciprocally tests for each other. When moist it vaporizes perceptibly, producing an odour similar to that of chlorine, but which yet has a peculiar character. The specific gravity of iodine in the solid state is 4.946.

2. The vapour of iodine is alleged to have the highest specific gravity of any known aëriiform fluid, being 8.716, nearly nine times as heavy as atmospheric air. In condensing it is peculiarly prone to crystallize, assuming the form of an elongated octoedron, with a rhomboidal base. Water does not dissolve more than  $\frac{1}{1000}$ th of its weight, giving a russet colour, but no taste. When the water is a salt added to it, especially muriate or nitrate of ammonia, it dissolves a larger quantity of iodine. The aqueous solution does not give out oxygen in the solar rays, and destroys vegetable colours. Iodine has a great analogy to chlorine and bromine, though more feeble in its affinities than either.

3. Soubieran recommends that, in order to apply starch as a test for iodine, the liquid to be essayed should be rendered slightly acid by means of nitric acid. After the addition and that of the starch, it will, in the course of an hour, acquire successively a reddish tint, a brownish blue, and finally a black colour; or, in other words, blue by its intensity, becomes equivalent to black. It has been alleged that in this way iodine may be detected in a liquid of which it forms only the  $\frac{1}{100000}$ th part.

4. Another mode is to include the liquid to be tested in a bottle made air-tight by means of a cork, from which is suspended a piece of moist paper sprinkled with finely

\* *Hydriodic* has hitherto been applied to this acid, but Thenard, as well as Berzelius, call it *iodohydric* acid. The considerations which induced me to make this change will be given hereafter.

powdered starch. If iodine be present, it tinge the starch. It is allowed by Baup that iodine may be thus discovered, when existing in a liquid, in a proportion no greater than that of a millionth.

735. Balard recommends that, after boiling the liquid with a small quantity of starch, a solution of chlorine in water be added by means of a tube descending to the bottom. The chlorine, at the line of contact, disengages the iodine from its combinations, and enables it to act upon the starch. I resorted to a similar process, about twenty years ago, using sulphuric acid in the manner in which the chlorine is employed by Balard.

### *Experimental Illustrations.*

736. A glass sphere containing iodine, on being warmed, appears filled with a violet-coloured vapour.

737. To a large glass vessel, containing some boiled starch diffused in water, a small quantity of iodine being added, the fluid becomes intensely blue.

### *Process for the extemporaneous Evolution of Iodine.*



738. Heat nearly to the temperature of ebullition about two ounces of concentrated sulphuric acid, in a glass globe like that represented in this figure.

739. It is preferable to have the whole of the globe heated, with due caution, over a large charcoal fire. Then quickly transferring it to the iron tripod, previously heated, and furnished with a small bed of hot sand, throw into the acid about half a drachm of iodide of potassium, sometimes called hydriodate of potash. Instantaneously the cavity of the globe will become replete with the splendid violet vapour of iodine, which will soon after condense, on those portions of the glass which are first refrigerated, in crystals, symmetrically arranged, of great beauty and unusual size.

## COMPOUNDS OF IODINE WITH OXYGEN.

*Of Iodic Acid.*

740. When iodine is subjected to a current of chlorous acid gas, previously dried by passing over chloride of calcium, the gas is absorbed, and a yellow liquid produced. From this, heat expels all the chlorine of the acid, while its oxygen, uniting with the iodine, forms iodic acid.

741. *Properties.*—Iodic acid is an inodorous crystalline solid, much heavier than water, with an acid and astringent taste. It deliquesces in moist air, but remains unaltered when the air is dry. In water it is soluble, but is precipitated from it by alcohol, in which it is insoluble. Its aqueous solution first reddens and then whitens litmus. With a great number of salifiable bases it forms salts, which detonate if mingled and ignited with any dry combustible matter. In common with bromic acid, it is decomposed by those acids which have hydrogen for their radical, and by many others which have not their highest proportion of oxygen. It contains one atom of iodine, and five of oxygen.

*Of Hyperiodic and Iodous Acid.*

742. An acid, containing more oxygen than iodic, has been recently discovered by Magnus, to which the name of hyperiodic has been given. But little has been ascertained respecting its properties. Sementini has asserted that he has discovered two additional compounds of oxygen with iodine, one of which he calls oxide of iodine, the other iodous acid. Their existence, however, requires farther confirmation.

*Of the Chlorides of Iodine.*

743. According to Thenard, chlorine forms with iodine a protochloride and a perchloride. The former contains one atom of each ingredient, the latter consists of five atoms of chlorine and one of iodine. The protochloride is the chloriodic acid of Davy.

744. To the perchloride the name of perchloriodic acid may be due. Thenard awards the appellation of acid to neither. Chloriodic acid is obtained by subjecting iodine in excess, to the action of chlorine. A liquid is produced of a deep reddish-brown colour, much heavier than water, and having in its mechanical properties a great analogy to bromine. It has an acid taste, and reddens litmus. Water dissolves it without sustaining or causing any decomposition, but abandons it to sulphuric ether. If the above-mentioned process be so varied as to have an excess of chlorine, perchloriodic acid is produced, which is a crystalline and volatile substance of a yellowish-white colour, and emitting an effluvium so irritating as to produce tears and a sense of suffocation.

*Of the Bromides of Iodine.*

745. Bromine combines with iodine in two proportions. A protobromide is obtained when iodine is subjected in excess to the action of bromine. It is solid, and when warmed affords reddish-brown vapours, which condense into crystals of the same tinge, in shape resembling fern leaves. By the same process, when the proportions are reversed, a perbromide results,

which is liquid. Both of these bromides are soluble in water, and without reddening litmus. Subjected to the action of the Voltaic pile, mine goes to the positive, iodine to the negative pole.

## SECTION V.

### OF FLUORINE.

7. In last edition of this Compendium it was stated, that as bearing the name at the head of this section, was inferred by many chemists; and that I had no doubt as to the existence of that statement was written, Baudrimont has succeeded in obtaining an energetic element, by passing fluoride of calcium, or preferably by heating a mixture of intimately mixed chlorine or calcium and binoxide of manganese, with concentrated sulphuric acid. It is to be remarked that this process does not evolve fluorine in a state of purity, in consequence of the simultaneous evolution of the silicofluoric acid in a small proportion.

741. *Fluorine*—Fluorine is described as a gas of a yellowish colour, with an odour of chlorine mingled with a smell of sugar. It is not condensed by water but not with glass. The observations upon it, so far as they extend, justify the inferences from its properties, which previous knowledge and reasoning had given; and go to confirm its pretensions to a place among halogen bodies of the basic class. (627, &c.) (633, &c.)

742. As there are no known compounds of fluorine with any of the elements comprised in the class to which it belongs, consistently with the arrangement to which I have declared my intention to adhere, no further consideration can be given to it, until the bodies are treated of with which its most important combinations are formed.

## SECTION VI.

### OF SULPHUR.

749. Sulphur is a mineral production, well known in commerce under the name of brimstone. It is sold both in rolls and in flowers. It is found pure in the vicinity of volcanoes, of which it is a product. In combination with metals it is widely disseminated. From some of its metallic sulphides, which are known under the name of pyrites, it may be obtained in the pulverulent form, to which the name of flowers has been given by sublimation.



. *Properties.*—Sulphur is yellow, inodorous, and in- becomes electric by friction, and is liable by the h of the hand to be fractured with a slight noise. It ates and burns with a feeble flame at  $180^{\circ}$ , and at  $225^{\circ}$ , and by pouring out the liquid portion, after ass is partially congealed, it may be obtained in is. In close vessels at the temperature of  $600^{\circ}$  it zes, or sublimes, and afterwards condenses in the nown form of flowers as above stated. The flowers the microscope ascertained to be crystalline, and nerally contaminated by a minute portion of sulphu- cid, which may be removed by repeated washing.

. All the metals, when presented, in thin leaves or r, to the vapour of sulphur without access of air, into combustion with it, forming compounds which een designated as *sulphurets*; but which, as I have ought to be called *sulphides*. (686–7.) Combustion issues when the metals in a divided state are heated sulphur. The sulphides, formed with the metals of rths and alkalies, are soluble in water. From the ing solution the sulphur is thrown down by acids. phosphorus, sulphur is susceptible of a slow as well ick combustion. In consequence of the low tempera- it which it is capable of becoming converted by com- n into sulphurous acid, sulphur may be burned out of owder without causing it to flash. If raised to the rature of  $369^{\circ}$ , it enters into a more active reaction. products of the combustion of sulphur are sulphurous mingled with a small portion of *anhydrous* sulphuric

The hue of the flame when the combustion is slow e; in oxygen its flame is of a splendid purple. Ber- alleges that when sulphur is rubbed on any body, a for instance, which has been previously warmed, h not sufficiently to inflame the sulphur, an extremely e blue flame is produced with a peculiar odour. This he conceives to be the effect of the evaporation, un- npanied by any combustion; “since a cold body held it is covered with the flowers of sulphur unchanged.” reason, however, appears insufficient; since the su- tion of one portion of the sulphur does not demon- e that another is not oxydized, any more than the de- ion of carbon upon a cold body exposed to a smoky , proves that another portion of carbon, arising from

the same source, cannot at the same time be converted into carbonic acid, as is known to be the fact.

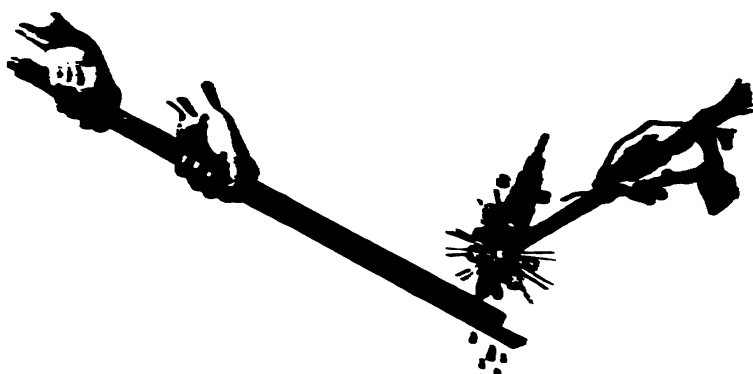
752. Some very curious anomalies have been observed respecting the phenomena of sulphur when kept over the fire after fusion, which the limits prescribed to this work will not allow me to introduce.\*

### *Experimental Illustrations.*

753. Sulphur exhibited in flowers and in rolls; also crystallized as abovementioned.

754. Combustion of Dutch gold leaf and of an iron bar by sulphur. Iron wire converted into a sulphide by the vapour of sulphur emitted in a jet from the touch-hole of a gun barrel, made red-hot in the vicinity of the aperture.

#### *The Combustion of Iron by a Jet of Vaporized Sulphur.*



755. If a gun-barrel be heated red-hot at the butt-end, and a piece of steel point be thrust into it, on closing the muzzle with a cork, or blowing into it, an upward jet of vaporized sulphur will proceed from the touch-hole. Exposed to this, a bunch of iron wire will burn as if ignited in oxygen gas, and will fall down in the form of fused globules, in the state of proto-sulphide. Hydrate of potash, exposed to the jet, forms not a sulphide of a fine red colour.

756. In order to designate the different proportions of oxygen existing in any oxide, relatively to the other ingredient, I employ the following nomenclature in accordance to the authority of Berzelius and others.

Oxygenized body.	Oxygen.	Appellation.
1 atom	1 atom	protoxide.
2 atoms	1 atom	oxide or subsulphide.
1 atom	2 atoms	sesquioxide or disulphide.

1 :	3 atoms	trioxide.
1 atom	4 atoms	quadroxide.
Either 2 atoms	3 atoms }	sesquioxide.
or 1 atom	1½	

757. The monosyllables *di*, *bi*, *tri*, *qua*, have an analogous influence on the meaning, when used before any other of the words employed as *ove*, to distinguish the compounds severally formed by the basacigen elements, (634.) hence we have *dichloride*, *protochloride*, *bichloride*, *trichloride*, *quadrichloride*, &c. It will be perceived that as in the terms *quaxide* and *quadrichloride*, the monosyllable *qua*, has such letters added as to render the resulting epithet easy to pronounce, and agreeable to the ear. 758. The second stage of combination in which the proportion of the retro-negative ingredient exceeds the ratio of equality, has been distinguished by prefixing the word *deuto*. Hence *deutoxide*, *deutochloride*, *deutobromide*, *deutiodide*. I prefer *bioxide*, as more precise and descriptive where the presence of two atoms is to be indicated. *Per* is prefixed to signify the presence of oxygen in a maximum degree, and in the case of *un*, is used to designate a *sesquioxide*, in that of mercury a *bioxide*. But *un* monosyllable is also prefixed to compounds containing any number of atoms, whether forming a base or an acid. Hence, we have an acid distinguished by the appellation *perchloric*, which contains seven atoms of oxygen. The syllables in question are prefixed by the French chemists to the words *chlorure*, *bromure*, *iodure*, *fluorure*, *cyanure*, as they are by the British chemists, prefixed to the modifications of those names which they employ.

### COMPOUNDS OF SULPHUR WITH OXYGEN.

One atom of sulphur, 16,	{ With two atoms of oxygen, forms sulphurous acid, equivalent . . . . .	32
	{ With three atoms of oxygen, forms sulphuric acid, equivalent . . . . .	40
Two atoms of sulphur, 32,	{ With two atoms of oxygen, form hyposulphurous acid, equivalent . . . . .	48
	{ With five atoms of oxygen, forms hyposulphuric acid, equivalent . . . . .	72

#### *Of Hyposulphurous Acid.*

759. This acid exists only in combination with salifiable bases, and of the salts formed I believe no useful application has been made. Any attempt to explain the method in which hyposulphites are produced, will be deferred until I reach the subject of the compounds formed by acids with metallic oxides.

#### *Of Sulphurous Acid.*

760. *Preparation.*—It is formed by the ordinary combustion of sulphur, or by boiling sulphuric acid on sulphur, on mercury, or on any other substance by which it may be partially deoxidized.

761. *Properties.*—Sulphurous acid is a colourless gas, possessing the well known odour of burning sulphur. It is incapable of supporting combustion, and is deleterious to life, a spasmodic closure of the glottis following any attempt to respire it.

762. It first reddens and then bleaches litmus, and destroys organic

colours generally. It is used on this account to bleach silk and wool. Sulphurous acid is soluble in water, which absorbs 43 times its bulk. A solution of this gas is exposed to the air, it absorbs oxygen, and is converted into sulphuric acid. This acid, with four times its bulk of water, forms a crystalline hydrate, which melts under  $40^{\circ}$ , disengaging the greater part of the acid. After being rendered anhydrous by passing over chloride of calcium, sulphurous acid gas, by exposure to a temperature of  $-12^{\circ}$ , condenses into a colourless, transparent liquid, having the specific gravity of 1.45. When dropped in vacuo on the bulb of a spirit thermometer, previously at  $50^{\circ}$ , and surrounded with cotton, the temperature of  $-90^{\circ}$  will be indicated. It is even said that alcohol has been frozen in this manner. Sulphurous acid gas is decomposed at a red heat, either by hydrogen or carbon. It is displaced from its combinations, by acids except cyanhydric (prussic) and carbonic acid.

*Impregnation of Water with Sulphurous Acid, by means of an appropriate Apparatus.*



763. Into the open neck of the tall receiver, a recurved glass tube is fastened, so as to descend several inches below the neck. The other end of the pipe turns in a brass socket, into which is inserted the stem of an inverted glass funnel. The receiver is placed over the shelf of a pneumatic cistern, covered an inch deep with water. The funnel includes a stand supporting a tumbler of the same liquid, pipe, extending from a siphon pump, rises within the receiver nearly as high as the stand. Under these circumstances, when the pump is put into action, the subsequent exhaustion of the receiver draws from the receiver water into it of the water from the cistern, until the resistance of this water opposes to a further elevation is greater than is opposed by the water in

the tumbler, to the entrance of air from the recurved pipe communicating with the funnel. The air of the funnel will then be drawn into the receiver through the liquid in the tumbler; and if sulphur, carbon, phosphorus, a candle, lamp, or inflammable gas be placed, while burning, under the funnel, the fumes may be drawn to pass through the water, which may be coloured by litmus, or may contain ammonia, baryta, or any other desirable agent, which it may be capable of dissolving or suspending.

### *Of Hyposulphuric Acid.*

764. This acid is obtained by passing sulphurous acid gas through a solution of peroxide of manganese suspended in water in a finely divided state. The mass be kept cold, the peroxide is reduced to the state of protoxide, the oxygen forms with the sulphurous acid, hyposulphuric acid. This, with the protoxide, produces a salt, which, remaining dissolved, may be purified by crystallization. By the addition of sulphide of barium to a solution of the resulting crystals, the manganese is precipitated in the state of a sulphide, and hyposulphate of baryta is obtained. From this the hyposulphuric acid may be separated by sulphuric acid, and concentrated by evaporation in vacuo, till it acquires the specific gravity of 1.45.

By heat or farther concentration, it is decomposed into sulphurous and sulphuric acid.

765. Hyposulphuric acid is a colourless, inodorous liquid, which reddens litmus, has an acid taste, and dissolves zinc with disengagement of hydrogen.

### *Of Sulphuric Acid.*

766. Sulphuric acid has been known since the close of the fifteenth century, when it was obtained by Basil Valentine by the distillation of green vitriol, or sulphate of iron.

767. *Preparation.*—This acid may be obtained by burning sulphur and nitre in chambers lined with lead, or by the process abovementioned, by which it was originally obtained; whence the almost obsolete name, *oil of vitriol*. It is best purified by distillation.

768. I shall defer for the present the illustration of the process for procuring sulphuric acid by sulphur and nitre; also any exemplification of its habitudes with other bodies.

769. *Properties.*—It is a liquid, oleaginous in its consistency, caustic when concentrated, intensely acid when dilute. When three parts are added to one of water, a boiling heat is produced. (350.) Hot water explodes with it as with a melted metal. It is diluted by the absorption of moisture when exposed to the air. No acid equals it in the power of reddening litmus. When pure it is colourless and has but little smell.

### *Of the Sulphuric Acid of Nordhausen, and of Anhydrous Sulphuric Acid.*

770. The sulphuric acid of Nordhausen differs from that in use in this country, in containing a portion of acid, which being free from water, is called anhydrous. This anhydrous portion being volatile, assumes the form of vapour, and, meeting with the moisture of the air, condenses into white fumes. (517.)

771. The fuming acid of Nordhausen is obtained by calcination and distillation from sulphate of iron, (known also by the name of green vitriol) contained in retorts of stone-ware. It may be obtained also from white vitriol or sulphate of zinc by similar treatment. The anhydrous acid may be separated from the other portion by gentle distillation, with the aid of a refrigerated receiver, previously well desiccated. It is a crystalline body resembling asbestos, and may be rubbed between the fingers like wax, without their being attacked. In the air it emits thick fumes having an acid smell. At a temperature above  $64^{\circ}$  it is liquid. Once congealed it cannot be fused without great care; as the temperature at which it is vaporized, is but little above that at which it liquefies. Hence it is apt to undergo a sudden enlargement of bulk which causes it to be thrown out of the containing vessel. When vaporized it forms a colourless gas. Neither

in this state nor in its crystalline form has it any effect on litmus rendered perfectly dry. When passed through a red-hot tube of pore it is resolved into oxygen and sulphurous acid.

772. Either caustic lime or baryta enters into a species of comb with this gas, forming with it a sulphate.

773. The solid anhydrous acid, thrown into water, produces a action resembling the effect of a hot iron, and, when mingled with an equal proportion of water, explodes with a force sufficient to fracture a vessel.

774. The fuming acid of Nordhausen is of use for the solution of is employed in dyeing; as the anhydrous acid answers better for this purpose than the aqueous.

775. It combines chemically in four proportions with water. The pound containing water in the least proportion is formed in some processes for producing the acid of Nordhausen. It is a crystalline liquid which probably consists of 2 atoms of anhydrous acid and 1 of water. Four parts of the anhydrous acid and about 1 of water form the concentrated acid of the shops, of the specific gravity of 1.85, which is considered to contain 1 atom of water to 1 of acid. When the acid is to the water 4 to 2, a compound results, of which the density is greater than the density of the constituents, and which probably consists of 2 atoms water to 1 of acid. A similar alteration of the density follows the addition of water until the specific gravity is reduced to 1.632.

#### *Of the Chlorides of Sulphur.*

776. According to Thénard, there are two chlorides which are liquids. One contains 3 atoms of sulphur to 1 of chlorine; the other atom of each ingredient. The protochloride is a yellow, viscid, oleaginous liquid, heavier than water, and which boils at  $239^{\circ}$ . The other is red brown, volatile, fuming and acrid, and boils at  $147^{\circ}$ . Both are decomposed by water and alcohol.

#### *Of the Bromide and Iodide of Sulphur.*

777. The flowers of sulphur dissolve in bromine, producing a reddish oleaginous, fuming liquid. When iodine is heated gently with sulphur forms a brilliant crystalline iodide, of a steel-gray colour.

## SECTION VII.

### OF SELENIUM.

778. In 1817, Berzelius, examining, in concert with Gahn, the method of preparing sulphuric acid, as practised at Gripsholm, in Sweden discovered a sediment in the acid, partly red, partly brown, which, treated by the blowpipe, produced the odour of a rotten radish, and left a small portion of lead. The odour thus evolved had been considered by Klaproth as an indication of tellurium. In consequence, Berzelius took care to direct all the deposition, produced in the manufacture of sulphuric acid, during some months; no other sulphur than that of Fahlun being employed.

The discovery of selenium resulted, to which he gave the name of selenium, from the Greek word *σεληνη*, the moon, suggested by its analogy with tellurium, named from tellus, the earth.

778. Selenium seems much distributed throughout nature. In Sweden it has been found combined some times with copper and silver, sometimes with copper only. A small quantity has been detected in cubic galena. In Norway it has been discovered united with tellurium and bismuth; in the Elster, combined with lead, copper, and mercury. Strömyer has found it in a mineral from the Lipari is combined with iron.

788. Preparation.—From selenium, in which it exists, it is separated, selenium is extricated by its action in aqueous regia, prepared by sulphuretted hydrogen, re-solution in aqua regia, precipitation by alkalis, filtration and evaporation, and addition of alcohol, on of the resulting mass, and sublimation. Selenium is produced by the reaction of selenium with oxygen in the aqua regia, is saturated by the potassium and afterwards deoxidized by the hydrosulphate of ammonia in the same manner employed, the selenium obtained by the heat.

791. Properties.—Selenium, on cooling after distillation, assumes a shining surface of a deep reddish-brown colour, with a metallic brilliancy resembling that of the blood-stone (hematite). Its fracture is conchoidal, vitreous, of a lead-gray, with metallic lustre. Very slowly refrigerated after fusion, its surface becomes granulated and uneven, of a reddish-gray, and devoid of lustre. By quick refrigeration the characters above indicated result. Selenium has little tendency to crystallize, yet it is capable of separating in a crystalline pellicle, or of forming a crystalline vegetation, upon the sides of the vessel, from a solution in the state of a selenhydrate. When precipitated cold from a diluted solution, whether by zinc or sulphuretted hydrogen, it is red like cinnabar. But if this precipitate be boiled, it turns black and consolidates, becoming heavier. When pulverized, selenium becomes of a deep red, and likewise when in very thin layers. With heat it softens, and at the boiling point of water, acquires a semifluidity, becoming completely fluid at a temperature somewhat higher. In cooling it remains soft for a long time, and may, like heated sealing-wax, be drawn out into filaments. These, by reflected light, are gray, with some metallic brilliancy, but, by transmitted light, are transparent, and of a ruby-red colour.

792. When selenium is heated nearly to redness in a distillatory apparatus, it assumes, with ebullition, the form of a vapour of a yellow colour, deeper than the hue of chlorine, yet lighter than that of sulphur. This vapour condenses in the neck of a retort in black drops, which coalesce like those which are formed by the condensation of mercury. When condensed with access of air, selenium appears like a red fume, and is deposited in a state analogous to the flowers of sulphur, but of a cinnabar-red colour. The smell of a radish is only perceived when the heat is sufficient to be productive of oxidation. The specific gravity of selenium is from 4.3, to 4.8.

#### *Compounds of Selenium with Oxygen.*

793. Selenium has but a feeble affinity for oxygen, yet forms a volatile oxide, which is either of radish or decayed radish. It forms also two acids the selenous and selenic. The latter of these is isomorphous with sulphuric acid. (474.)

784. Selenious acid is procured by the action of selenium on hydrogen gas, or by reaction with nitric, or nitromuriatic acid.

785. Selenic acid is obtained by the deflagration of nitre with selenium in a hot crucible; a seleniate of potash results, which is decomposed by nitrate of lead, and the resulting seleniate of lead is decomposed by phuretted hydrogen. The sulphuret of lead precipitates, while selenium is dissolved in the water employed. When heated to 280 degrees, it is at its highest concentration, and at 290 degrees is decomposed into oxygen and selenious acid.

786. The highest specific gravity of selenic acid is 2.6. It remains sulphuric acid in its consistency, in its evolving heat by dilution with water, and in the power of dissolving iron and zinc, with the evolution of hydrogen. It cannot be rendered anhydrous. When its density is at the maximum, it contains 16 per cent. of water. With the aid of heat, it oxidizes and dissolves copper and even gold, but not platinum. With chlorosulphuric acid, it constitutes a sort of aqua regia, which dissolves both gold and platinum. Its salts cannot be separated from the sulphates, unless by the property of detonating with potassium at a red heat, and that of causing evolution of chlorine, when boiled with muriatic acid. Selenic acid can be separated from sulphuric acid by saturation with potash, and then with sal ammoniac. The selenic acid is decomposed into selenium and hydrogen of the ammonia.

787. Selenium combines with chlorine and bromine, and with sulphur in every proportion.

788. As there is not one of the metals which have decided preponderance of the metallic character, which is not an excellent conductor of both heat and electricity, and as metallic brilliancy is another striking attribute of the metallic genus, I cannot understand wherefore selenium, which is admitted to be destitute of the two first mentioned characteristics, and to possess the third imperfectly, should be received into the class of metals; while carbon, which in the form of plumbago, is endowed with them all, is excluded. I cannot consider selenium as a metal. It is stated to have the brilliancy of hæmatite, which is, I conceive, inferior in that respect to plumbago, but Berzelius considers as pure carbon.



## SECTION VIII.

### OF TELLURIUM.

○ 789. A metal has been found in the veins of auriferous silver in the mines of Transylvania, which has been called tellurium. It is found in small quantities in Norway, united to selenium. Tellurium has likewise been discovered in Connecticut. It is found chiefly in the state of an alloy with gold and silver.

790. Tellurium displays a metallic brilliancy, and is of a colour like that of tin and antimony, and of a lamellated structure. When melted in a glass vessel, replete with hydrogen, and slowly cooled, it assumes the appearance of burnished silver. Fused in a vessel, it presents crystalline determinable form. It fuses below a red-heat, and above that temperature is volatilized. When heated before the blowpipe, it takes fire, and with a blue flame bordering on green, and is dissipated in gray p



ness, which has the smell of horse-radish. This smell is ascribed by Berzelius to the presence of selenium. Latterly the same author assigns its specific gravity to be 6.2324.

791. Tellurium may be oxidized either by combustion or by nitric acid. Heated, exposed before the blowpipe upon charcoal, is decomposed with passive violence.

792. Berzelius alleges that tellurium will dissolve in concentrated sulphuric acid without being oxidized, in which it differs from other metals. In that it forms a soluble oxysulphide. The colour of the resulting solution is purplish-red. Tellurium is more especially entitled to our notice on account of its great analogy to sulphur and selenium, and of its forming both acids and bases, which uniting, form telluri-salts. It is upon this ground that Berzelius includes it in his amphigen class, and that I consequently place it among the base bodies.



## OF RADICALS.

793. Radicals are bodies capable of forming with a basigen body either an acid or a base, and are divided into those which are *metallic*, and those which are *non-metallic*. (63.)

### OF NON-METALLIC RADICALS.

The bodies which I place under this head are:—

Hydrogen,  
Nitrogen,  
Phosphorus,  
Carbon,

Boron,  
Silicon,  
Zirconion.

## SECTION I.

### OF HYDROGEN.

794. In its gaseous state, it is the principal constituent of all ordinary flame. It is an ingredient in water, and combined with oxygen and carbon, it is found in all vegetable and animal substances. It derives its name from *hydro*, water, and *genes*, to produce.

795. Preparation.—Per se, hydrogen exists only in the gaseous state. In this form it may be obtained by the reaction of diluted sulphuric or muriatic acid with zinc or iron, or of steam with iron turnings, made red-hot in a gun barrel. It may be evolved in a state of purity, and con-

sequently destitute of odour, from pure water, by Voltaic agency, or by reaction with an amalgam of potassium.

*Self-regulating Reservoir for Hydrogen and other Gases.*

796. The following figure represents a self-regulating reservoir for hydrogen gas.



797. This very conspicuous engraving can require but little explanation. Suppose the glass jar without to contain diluted sulphuric acid; the inverted bell, within the jar, to contain some zinc, supported on a tray of copper, suspended by wires of the same metal from the neck of the bell. The cock being open when the bell is lowered into the position in which it is represented, the atmospheric air will escape, and the acid, entering the cavity of the bell, will, by its reaction with the zinc, cause hydrogen gas to be copiously evolved. As soon as the cock is closed, the hydrogen expels the acid from the cavity of the bell;

and, consequently, its reaction with the zinc is prevented, until another portion of the gas be withdrawn. As soon as this is done, the acid re-enters the cavity of the bell, and the evolution of hydrogen is renewed and continued, until again arrested, as in the first instance, by preventing the escape of the gas, and consequently causing it to displace the acid from the interior of the bell, within which the zinc is suspended.\*

798. By means of apparatus of this kind, I have been enabled to have self-regulating reservoirs of nitric oxide, of sulphydric acid, of carbonic acid, of chlorine, and of chlorohydric acid, merely by changing the materials, and making such a modification of the means of supporting them as the agents employed or evolved require.

\* The principle of this apparatus is analogous to that which was contrived by Gay-Lussac. I had employed the same principle, however, when at Williamsburg, to moderate the evolution of carbonic acid, before I had read of Gay-Lussac's apparatus. I prefer the modification above described. In the first place, it is internally more easy of access for the purpose of cleansing; secondly, it is much better qualified for containing sulphuret of iron, or marble, for generating sulphuretted hydrogen, or carbonic acid gas; and thirdly, by raising the bell glass, until the liquid within and without is on a level, the pressure may be removed.

In the other form, the pressure on the gas is so great, that, unless the tube, the cock, and the junctures be perfectly tight, there must be a considerable loss of materials; since the escape of gas inevitably causes their consumption, by permitting the acid to reach the zinc, or other material employed.

*Large Self-regulating Reservoir for Hydrogen.*

V.



799. This figure represents a self-regulating reservoir for hydrogen, constructed like that described in the preceding article; excepting that it is about fifty times larger, and is made of lead, instead of glass. This reservoir may be used in all experiments requiring a copious supply of hydrogen. When gas is to be supplied to the hydro-oxygen, or compound blowpipe, the perforated knob at the end of the pipe, which has an orifice on one side, is placed under the gallows, G, (seen in the fig. of the compound blowpipe, 331) and fastened airtight to the pipe of that instrument, by the pressure of the screw of the gallows. The gas is retained, or allowed to flow through the pipe, by means of the valve cock, V, which is much less liable to leak, than one of the common form.

**Properties of Hydrogen.**—It is the lightest of all gaseous substances. One hundred cubic inches weigh 13 grains. Its weight to that of oxygen is as 1 to 8. Its specific gravity, the gravity of air being assumed as 1.0689. It is about 200,000 times lighter than water, and 300,000 times lighter than platinum. In its gaseous state it smells unpleasantly. When pure it is colourless. In its nascent state, as when liberated from an acid, it is extremely prone to take up a portion of sulphur, phosphorus, arsenic, or of some metals. Of the last mentioned property, a most useful application is now made, which I shall mention when I describe the process for detecting arsenic.

The respiration of hydrogen, mixed with the same proportion of oxygen as exists in atmospheric air, is not attended by any oppressive sensations; yet a profound sleep has been induced in animals surrounded

by such a mixture. When breathed either in this way unmixed, it will be found to produce a ludicrous alteration in a man's voice, making it shrill and puerile, and so of character as not to be recognised. Sound is said to move in this gas with a velocity three times as great as in the atmosphere. According to the experiments of Leslie, the sound of a clock bell was as feeble in hydrogen as in air rarefied one hundred times. By no degree of pressure which has been tried, can hydrogen be condensed into a liquid. In consequence of its levity, it escapes rapidly from an open vessel, unless inverted. It is eminently inflammable, yet a taper when immersed in it is extinguished. A jet of it, ignited, appears like a feeble luminous candle flame, and, if surrounded by a glass tube, produces a remarkable sound.

802. It has been stated that for equal volumes, all gases have the same capacity for heat; it follows, that for equal weights, the capacities must be inversely as their specific gravities or their densities. Hence hydrogen having the lowest specific gravity, will have the highest specific heat (257.) It is in fact calculated to be as to that of an equal weight of air as 13.08 is to 1, and to that of an equal weight of water as 3.88 to 1. Its refracting power is one and a half times greater than that of the atmosphere.

803. When mixed with oxygen or atmospheric air, and subjected to flame, an electric spark, or a wire ignited by galvanism, it explodes. With chlorine it explodes under like circumstances, and likewise in the solar rays. When burning, it disengages sufficient heat to melt 315 times its weight of ice. Dobereiner discovered that platinum sponge, a cold metallic congeries, becomes ignited on entering a mixture of hydrogen with oxygen gas, and causes it to inflame by an agency which has not been satisfactorily elucidated. It has since been discovered that palladium, rhodium, and iridium possess this property in nearly the same degree. I have ascertained that if asbestos, charcoal, or clay be soaked in chloride of platinum, and afterwards desiccated and heated red-hot, the property of inflaming a mixture of hydrogen and oxygen is acquired.

#### *Experimental Illustrations of the Properties of Hydrogen*

804. Levity of the gas demonstrated by the ascent of a balloon, or by the effect of filling with hydrogen

glass globe balanced upon a scale beam. (71, &c.) Effect upon the voice shown. Inflammation of a gaseous mixture of hydrogen with atmospheric air by platinated asbestos, or platinum sponge. Apparatus for lighting a candle by a jet of hydrogen from a self-regulating reservoir, either by the electric spark or platinum. (327.) A mixture of hydrogen and oxygen, ignited within a small cannon, explodes.



*Candle extinguished and re-lighted by Hydrogen.*

805. If a lighted candle be introduced into a wide-mouthed inverted phial, filled with hydrogen gas, the flame of the candle will be extinguished from the want of oxygen. Meanwhile, at the mouth of the bottle, where there is a sufficient access of air, the gas will have taken fire, and will burn with a lambent flame scarcely visible in daylight. Hence if the candle be slowly withdrawn, it will be re-lighted as it passes through the flame.

*Philosophical Candle.*

806. Small pieces of zinc or iron, being introduced into a glass flask, so as to occupy about one-eighth of its capacity, provide a suitable cork, so perforated as to receive a glass tube terminating in an orifice just large enough to admit a common brass pin. Pour upon the zinc five parts of water, and adding one of sulphuric acid, fasten the cork, with its tube inserted, into the mouth of the flask. After all the atmospheric air has escaped from the vessel, on applying the flame of a candle to the orifice of the tube, it will be surmounted by an inflamed jet of hydrogen, which has been called the philosophical candle.

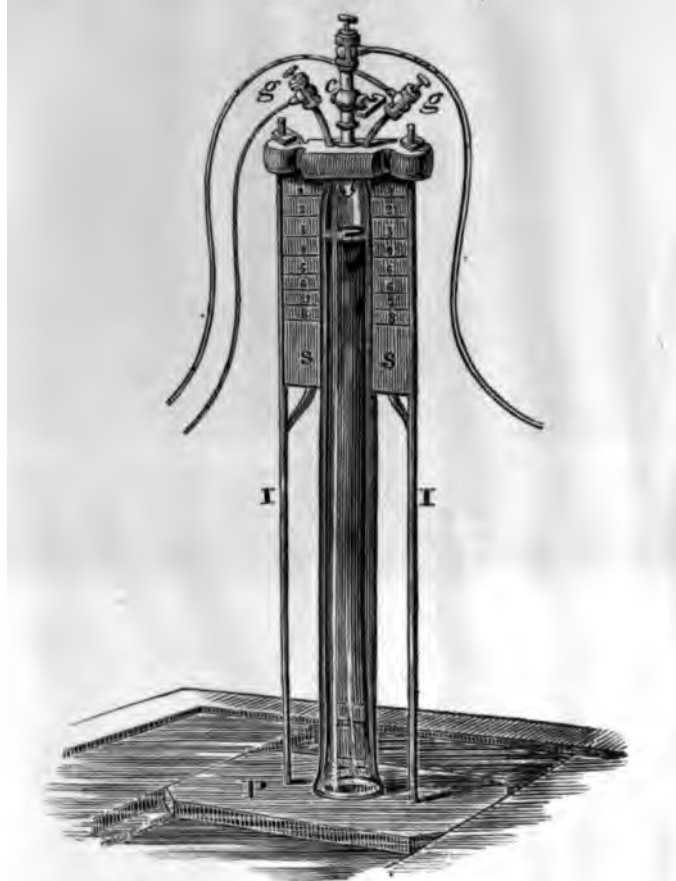
807. The light given out by the flame of pure hydrogen, is, nevertheless, wholly incompetent to answer the purpose of candle light; but I have ascertained, that the addition of a small quantity of spirit of turpentine to the materials obviates this defect.







*Volumescopie.*





cern, the orifice open for the air to escape. Then invert it, the orifice being kept under the surface of the water. Next fill it with the mixture to be analyzed, as for instance a mixture of equal volumes of hydrogen and atmospheric air. Shut the orifice by moving the slide, allow any excess of air to escape, and then, placing the orifice of the measure under the pedestal of the eudiometer, open the orifice: the gaseous mixture will mount into the cavity of the cylinder. Shut the lower cock, and pass an electric spark through the included mixture. An explosion will ensue, and consequently a portion of the mixture will be condensed into water. By opening the cock, B, the deficit, thus produced, will be compensated by the entrance of an equivalent bulk of water. Open the upper cock, and allow the residual gas to mount into the graduated tube. Detach this tube from the eudiometer, and closing the orifice with the finger under water, before lifting it from the basin, sink it in water, until this liquid be as high without as within the tube. It may now be seen how far the residual air falls short of the 100 measures introduced.

814. It must be evident that we might operate on double the quantity of gas, by taking the measure full of it twice instead of once; and that a mixture of two volumes of air and one volume of hydrogen might be analyzed, by taking three measures equivalent to 300 parts. The loss by the explosion would be the number of degrees that the residue would fall short of 300, when in the graduated tube.

815. A mixture of three volumes of hydrogen with one of impure oxygen might be analyzed by taking the measure twice full, which is the same as 200 parts. In this case, one-third of the deficit would be the quantity of pure oxygen in  $\frac{1}{4}$  of 200, or 50 parts, of the impure gas.

816. The metallic scale accompanying the cylinder I have never used. Since one of its divisions is equivalent to ten of those on the tube, observations made by means of the latter must be ten times more accurate.

817. Instead of resorting to an electric spark to produce the inflammation of the gases, I have added to this eudiometer a *galvano-ignition apparatus*. (335,) by means of which a gaseous mixture may at any time be ignited with certainty.

#### Of the Volumescop.

1. In experiments performed with such eudiometers as are mentioned above, the steps of the process cannot be made evident to a numerous class, so as to enable them to judge of the result by inspection. In order to attain this object, I have contrived the apparatus represented on the opposite page, which I have called a volumescop, as I find it very inconvenient not to have a name for every variety of apparatus. It consists of a very stout glass tube, of 30 inches in height, and tapering in diameter inside from 2 and  $\frac{1}{4}$ th to 1 and  $\frac{1}{4}$ th inches. The least thickness of the glass is at the lower end, and is there about  $\frac{5}{16}$ th of an inch. There is an obvious increase in thickness towards the top, within the space of about 6 inches. The tube is situated between the iron rods, l l, which are riveted, at their lower ends, to a metal plate of the same metal, let into the lower surface of a square piece of plank. The piece of plank supports the tube, so as to be concentric with an aperture corresponding with the bore of the tube, and constituting effectively its lower orifice. The upper orifice of the tube is closed by a stout block of mahogany, which gives a disk of gum elastic in a corresponding hollow, made by means of a lathe, to be of the same diameter as the end of the tube. Into a perforation in the

centre of the mahogany block, communicating with the bore of the tube, a cock, *c*, furnished with a gallows screw, is inserted. Through the block, on each side of the perforation, wires are introduced, so as to be air-tight. To the outer ends of these wires two gallows screws, *g g*, are soldered; to the inner ends a platinum wire, so as to form a galvanic-ignition apparatus. (335.)

819. The apparatus being thus constructed, let it be firmly fixed over the pneumatic cistern, so that the water may rise about an inch above the lower extremity of the tube. To the gallows screws, *g g*, attach two leaden rods, severally proceeding from the poles of a calorimotor. By means of a leaden pipe, produce a communication between the bore of the cock and an air pump, so that by pumping the air from the cavity of the tube, the water of the cistern may be made to rise into the space thus exhausted of air. On each side of the tube, and between it and each iron rod, there are two strips of wood *S S*, scored so as to graduate about seven inches of the tube into eight parts. The various distances between these graduations were ascertained by introducing into the tube, previously filled with water, exactly the same bulk of air eight times, and marking the height of the water after each addition. By these means the instrument is graduated into eight parts of equal capacity; and we are by aid of it enabled to measure the gases, and to notice the diminution of volume resulting from their spontaneous reaction, or that which may be induced by the ignition of the wire.

820. The voluescope being so far prepared, and the tube exhausted of air so as to become full of water, close the cock leading to the air pump, and introduce two volumes of pure hydrogen and one volume of pure oxygen, which may be most conveniently and accurately effected by the sliding-rod gas measure. The plates of the calorimotor being in the next place excited by the acid, the ignition of the platinum wire ensues, and causes the hydrogen and oxygen to explode. When they are pure, the subsequent condensation is so complete, that the water will produce a concussion as it rises forcibly against the gum elastic disk, which, aided by the mahogany block, closes the upper orifice of the tube.

821. If the preceding experiment be repeated with an excess of either gas, it will be found that a quantity, equal to the excess, will remain after the explosion. This is very evident when the excess is just equal to one volume, because, in that case, just one volume will remain uncondensed. By these means, a satisfactory illustration is afforded of the simple and invariable ratio in which the gaseous elements of water unite, when mixed and inflamed; which is a fact of great importance to the atomic theory, and to the interesting theory of volumes which hereafter I shall have occasion to notice.

822. Since the accompanying engraving was made, a plate of brass, about a half an inch in thickness, has been substituted for the mahogany block. This plate was made true by means of the slide lathe, the holes for the cocks entering upon the side, and extending inwards and downwards, so as to open into the bore of the tube, when the plate is in its place.

823. It has been found to contribute much to convenience in manipulating with this instrument, to have a vessel, an iron mercury bottle, for instance, such as represented in page 69, (396), interposed between the air pump employed, and the voluescope, so as to be exhausted before performing an experiment. Thus assisted, in order to cause the tube to be filled with water, it is only necessary to turn the key of the proper cock. Moreover, by this expedient, the water is prevented from reaching the pump, and when corrosive vapours are produced, lessens the danger of their injuring the mechanism of that instrument.

## COMPOUNDS OF HYDROGEN WITH OXYGEN.

### *Of Water.*

824. This liquid may be produced by the combustion of hydrogen gas with oxygen gas. It may be decomposed by passing it in steam over iron, ignited in a gun barrel; also by the aid of acids, by the alkaline metals, by sulphurets and phosphurets, by electricity, by galvanism, and by vegetable leaves.

825. Water is necessary to some crystals and to gal-

unic processes. Its powers as a solvent are peculiarly extensive, and are increased by heat and pressure.

826. Water is one, among other substances, which acts as an acid with powerful bases, while with powerful acids it acts as a base. Berzelius, in some instances, calls it hydric acid. It will be seen, as we proceed, that it combines with various metallic oxides, especially those which constitute the alkalies and alkaline earths. With the latter especially it produces much heat in combining, as exemplified in the slaking of lime; and in several of its combinations with them, its affinity is too energetic to be overcome by any degree of heat. Excepting acids, any compound in which water exists as an essential constituent, is called a *hydrate*. Thus slaked lime is a hydrate of lime; but this term is inappropriate, when applied to the compounds which it forms with acids. To them the term *aqueous* is applied by Berzelius. The absence of water in any substance in which it is liable to be present, is signified by the word *anhydrous*. I infer then that its presence should be indicated by means of the adjective *hydrous*. The vaporization and evaporation of water has, I trust, been sufficiently illustrated. (177, 229, 234.) As a moving power for machinery, as the source of rain, and as the cause of earthquakes, aqueous vapour is, obviously, for good or for evil, one of the most potent agents of nature.

The equivalent of oxygen being	8
And that of hydrogen	1
	<hr/>
Water is represented by	9

*Experimental Illustrations of the Agency of Water.*

827. No reaction ensues between tartaric acid and carbonated alkali until water is added, when a lively effervescence ensues.

828. Concentrated sulphuric acid and zinc remain inactive until water is added, when a copious evolution of hydrogen follows.

829. If nitrate of copper be rolled up in tin foil without moisture, the mass will remain inert; but if moistened before it is rolled up, ignition will be produced.

*Aqueous Vapour or Steam decomposed by ignited I*

830. Having introduced some turnings of iron or card teeth into an old musket barrel, lute into one it the beak of a half-pint glass retort, about half water; into the other end, a flexible leaden tube. I cover off the furnace, and place the barrel across that the part containing the iron turnings may be e to the greatest heat. Throw into the furnace a r of charcoal and live coals. The barrel will soon l white-hot. In the interim, by means of a chau coals, the water being heated to ebullition, the st made to pass through the barrel in contact with the iron turnings. Under these circumstances, the oxy the water unites with the iron, and the hydrogen ( in the gaseous state through the flexible tube.

831. The decomposition of water by sulphurets phurets, and the alkaline metals will be illustrated time.

*Water produced by an inflamed Jet of Hydroge*

832. The recomposition of water may be render dent, by means of the philosophical candle, (305,) other inflamed jet of hydrogen, situated within



*Apparatus for the Recomposition of Water.*

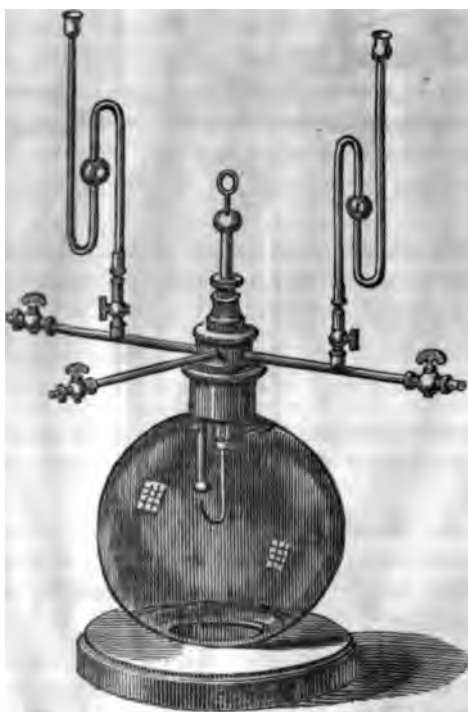


(Page 153.)

glass globe. The glass becomes immediately covered with dew, arising from the condensation of aqueous vapour, produced by the union of the oxygen of the air with the hydrogen.

*Lavoisier's Apparatus for the Recomposition of Water.*

**R.** This apparatus consists of a glass globe, with a neck cemented into a brass, from which three tubes proceed, severally communicating with an air pump, with reservoirs of oxygen and hydrogen. It has also an insulated wire for producing the inflammation of a jet of hydrogen by means of an electric spark. In order to put the apparatus into operation, the globe must be exhausted of air, and supplied with oxygen to a certain extent. In the next place, hydrogen is allowed to enter in a jet, which is to be inflamed by an electric spark. As the oxygen is consumed, more is to be admitted.



**R.** I have employed a wire ignited by galvanism to inflame the hydrogen in this tube, and conceive it to be a much less precarious method than that of employing an electrical machine, or electrophorus. (839).

*Description of an improved Apparatus for the Recomposition of Water.*

**R.** This apparatus is represented by the opposite engraving. An inverted bell, with a conical neck, is so closed at the apex in the making, as to form a transverse cavity, suitable to render the presence of a very small quantity of coloured liquid perceptible to the eye.

**L.** By means of the screw rod and plate frame, (248,) this bell glass is secured in an inverted position and made air-tight. With the aid of three valve cocks, V V V, many leaden pipes, communications with an air pump, a barometer gauge, &c. may be sufficiently supplied with oxygen, may be severally opened or closed at pleasure. Through a stuffing box which surmounts the plate, a copper pipe, P

is so passed as to occupy the axis of the bell glass, and that of - oil of platinum wire, appertaining to a galvano-ignition apparatus, (335, &c.) The copper pipe terminates below in a small platinum tube, and above, outside of the receiver, in a cock C, and gallows screw, by which and a leaden pipe, a communication with a self-regulating reservoir of hydrogen is at command.

837. The apparatus having been thus arranged, the bell is to be exhausted, and oxygen admitted, until the gauge indicates the pressure within the receiver to be nearly the same as that of the atmosphere. In the next place, the platinum wire being ignited, a jet of hydrogen is admitted, which of course inflames, and continues to burn so long as the supply of the gases is kept up. Soon after the inflammation of the hydrogen, the resulting water will be seen to coat the interior of the bell glass in drops, resembling a heavy dew, and, continuing to accumulate, will descend in streams into the converging neck of the bell glass. By surrounding this with cold water, the condensation may be expedited, and the deposition of water soon rendered strikingly evident. The gauge employed in this process is that already described. (137, &c.)

838. *Of the Air in Water.* Water naturally contains air. It is to receive the influence of the oxygen of the air thus existing in water, that fishes are furnished with gills, which perform to a certain extent the office of lungs in decarbonizing blood. Fishes cannot live in water which, either by boiling or exhaustion, has been entirely deprived of air.

839. The habitudes of other gaseous substances with water will be more advantageously illustrated, when those substances are under consideration.

### *Experimental Proof of the Presence of Air in Water.*

840. Water exposed to the action of an air pump, or otherwise subjected to exhaustion, becomes replete with air bubbles.

841. *Of the Moisture in Air.*—Air is not more invariably attendant upon water than water is upon air; nor is the air in water more necessary to fishes, than the water in the air to animals and vegetables. (229, &c.)

842. The well known deleterious influence of the winds which blow from the African deserts, arises probably from their aridity. The desiccating power of air is directly as its temperature, and inversely as the quantity of moisture previously associated with it.

843. There is a certain proportion of moisture, relatively to the temperature, which is most favourable to our comfort. If the moisture be increased without raising the temperature, or the temperature be increased without an accession of moisture, we are incommoded. In the one case, the skin becomes unpleasantly dry; in the other, the air is too much encumbered with aqueous vapour, to allow



perspiration, whether sensible or insensible, to proceed with sufficient freedom.

844. Stove rooms are oppressive on account of the too great aridity of the air in them; and hence the well known remedy of a basin of water, placed upon the stove to furnish moisture by its evaporation.

845. *Hygrometric Process of Dalton.*—The dew which is observable in vessels containing cold water, in warm weather especially, arises from the condensation of the aqueous vapour in the air.

846. According to Mr. Dalton, the less the degree of cold requisite to produce this phenomenon, the greater the quantity of moisture in the air. Hence, by ascertaining the highest temperature at which the water is capable of producing the condensation, the quantity of moisture may be known from a table which he has constructed. (229, &c.)

847. *Daniell's Hygrometer.*—Mr. Daniell has contrived an hygrometer upon the principle thus suggested by Dalton. Vaporization is ingeniously applied to produce cold in one bulb of the instrument, in consequence of the cold produced by the evaporation of ether in another bulb, as in the cryophorus. (407, &c.) Two thermometers accompany the instrument, one within the bulb refrigerated by the vaporization; the other so situated as to indicate the temperature of the atmosphere. As the quantity of aqueous vapour in the air diminishes, the depression of temperature necessary to the precipitation of moisture on the refrigerated bulb increases. The extent of the depression is ascertained by the thermometers, the quantity of water in the air by reference to a table.

848. *Organic Sensibility of the Beard of the Wild Oat (Avena Sensitiva) to Moisture.*—Hygrometers have been made which are dependent upon the contraction or dilatation which catgut, whalebone, and other substances of a like nature undergo, in proportion to the quantity of moisture in the air. Among instruments of this kind, that formed by means of the beard of the wild oat is pre-eminent for its susceptibility to the influence of moisture. Breathing on it through a minute hole in the case, causes the index to be moved instantaneously. (222, &c.) The indications of hygrometers thus constructed are not referrible to any standard, agreeably to which a comparison can be made between the dryness of the air in different places at the same time, or in the same place at different times.

849. *Hygrometric Process by means of a Balance.*—It may be presumed that the quantity of moisture in the air is inversely as the weight of water which will in a given time evaporate from a moist surface. If this presumption be correct, the little square dish here represented may, with the aid of a delicate scale beam, be used as an hygrometer. If it be suspended to the balance, and equipoised while containing a little water, the counter-weight will in a few minutes preponderate, in consequence of the loss by evaporation.



850. The loss of weight within any known period being determined, the vaporizing power of the air will be as the loss of weight; but as the evaporation is more or less rapid in proportion as there may be more or less agitation, it will not be right to infer that the quantity of aqueous vapour in the atmosphere is inversely as the rate of evaporation, unless the process

were uninfluenced by the wind. Of course the dish should be of convenient dimensions, accurately determined; 2 inches square for instance.

*Compounds of Chlorine with Water.*

851. *Hydrate of Chlorine*.—Berzelius observes that chlorine furnishes the only instance of an elementary substance capable of entering into combination with water. I allude here to a crystalline compound formed by passing the gas through that liquid at a temperature below 40° F. The hydrate thus formed is capable of being sublimed from one part of the containing vessel to another, in consequence of a slight diversity of temperature. It consists of one volume of chlorine, and twenty volumes of aqueous vapour.

852. *Solution of Chlorine in Water*.—The same eminent author alleges that, in order to obtain a saturated solution of chlorine in water, it is necessary, in the first instance, to expel from the latter all the atmospheric air.

*Of the Deutoxide or Bioxide of Hydrogen, or Oxygenated Water.*

853. In 1818, Thenard discovered that water might be made to receive an additional quantity of oxygen, by dissolving deutoxide of barium in liquid muriatic acid, precipitating the baryta by sulphuric acid, and the chlorine by silver.

854. *Properties*.—The bioxide of hydrogen is as liquid, and as devoid of colour as water. It is nearly inodorous, whitens the tongue, inspissates the saliva, and tastes like some metallic solutions. Applied to the skin, it creates a smarting sensation, more durable in some persons than in others. Its specific gravity is 1.452. Hence, when poured into water, it descends through it like syrup, but is dissolved by agitation. As it is less easy to vaporize than water, it may be separated from that liquid, by exposure in vacuo over sulphuric acid. (309.) In its most concentrated form, it has not been congealed by any degree of cold to which it has been subjected. The most surprising property of this substance is that of giving off oxygen explosively, on being brought into contact with substances which do not unite with either of its ingredients. Thus it explodes by contact with finely divided silver, platinum or gold, and still more actively with oxide of silver or peroxide of lead. The difficulty of explaining these phenomena has already been noticed. (421, &c.)

855. When mingled with the mineral acids, its liability to decomposition is diminished. If exposed to heat in its

most concentrated state, a few grains create a violent explosion. When, by dilution with 20 parts of water and exposure to heat, it loses all the oxygen which it holds beyond the quantity necessary to the composition of water, as much oxygen is found to be evolved as the hydrogen in the residual water retains. Hence it is generally supposed to consist of one atom of hydrogen and two of oxygen.

### *Remarks on Nomenclature.*

556. Some of the most eminent European chemists have, most erroneously and inconsistently, designated the acids formed by hydrogen, with the electro-negative, or basacigen bodies, as *hydracids*; while analogous compounds, formed by other radicals, were designated by prefixing syllables indicative of the electro-negative ingredient. Thus we have had hydrochloric, hydrobromic, hydriodic, hydrofluoric, hydrocyanic, &c., to signify the acid compounds of hydrogen with the halogen elements; while we have had fluoboric and fluosilicic to signify acids formed with the radicals boron and silicon by fluorine. Thus the former series is characterized by letters taken from the radical, the latter by letters taken from the electro-negative or basacigen ingredient, while hydrogen is placed by the side of oxygen, with which, in properties, it is extremely discordant. (633, 636.)

557. This error I pointed out in an article published in the *Journal of Pharmacy*, in the autumn of 1833, and in a letter to Professor Silliman.\*

\* The following passage is in the letter to which I have referred.

"In common with other eminent chemists, Berzelius has distinguished acids in which oxygen is the electro-negative principle, as *oxacids*, and those in which hydrogen is a prominent ingredient, as *hydracids*. If we look for the word radical in the table of contents of his invaluable Treatise, we are referred to p. 218, vol. 1st, where we find the following definition, "*the combustible body contained in an acid, or in a salifiable base, is called the radical of the acid, or of the base.*" In the second vol. page 143, he defines hydracids to be "those acids which contain an electro-negative body combined with hydrogen;" and in the next page it is stated, that "hydracids are divided into those which have a simple radical, and those which have a compound radical." The second only comprises those formed with cyanogen and sulphocyanogen. Again, in the next paragraph, "no radical is known that gives more than one acid with hydrogen, although sulphur and iodine are capable of combining with it in many proportions. If at any future day more numerous degrees of acidification with hydrogen should be discovered, their denomination might be founded on the same principles as those of oxacids." Consistently with these quotations, all the electro-negative elements forming acids with hydrogen are radicals, and of course, by his own definition, combustibles; while hydrogen is made to rank with oxygen as an acidifying principle, and consequently is neither a radical nor a combustible. Yet, page 144, vol. 2d, in explaining the reaction of fluoboric acid with water, in which case fluorine unites both with hydrogen and boron, it is mentioned in the instance among others in which fluorine combines with *two combustibles*.

"I am of opinion that the employment of the word hydracid, as co-ordinate with acid, must tend to convey that erroneous idea, with which, in opposition to his own definition, the author seems to have been imbued, that hydrogen in the one case, plays the same part as oxygen in the other. But in reality, the former is essentially a combustible, and of course the radical by his own definition.

"Dr. Thomson, in his system, does not recognise any class of acids under the appellation of hydracids, but, with greater propriety as I conceive, places them under names indicating their electro-negative principles. Thus he arranges them as oxygen acids, chlorine acids, bromine acids, iodine acids, fluorine acids, cyanogen acids, sulphur acids, selenium acids, and tellurium acids. These appellations might, I

Afterwards I had the satisfaction of observing, that, in an edition of his *Traité*, then in the press, Thenard was acting upon a similar view of this subject, and employing the language which I had suggested. Moreover I found that Dr. Thomson had not arranged the acids alluded to under the name of *hydracids*, but had put each of them under the name of its electro-negative ingredient. Hence they were treated of under as many heads as there are basacigen bodies. Or, to be more particular, they were treated of as oxygen acids, *chlorine acids*, *bromine acids*, *iodine acids*, *fluorine acids*, *cyanogen acids*, *sulphur acids*, *selenium acids*, and *tellurium acids*.

858. Consistently with the process of abbreviation by which oxacid has been employed to designate an acid formed by oxygen, and hydracid to signify an analogous combination formed with hydrogen, I have made the following abbreviations of the appellations employed by Thomson:—

For Oxygen acids	to use	Oxacids.
„ Chlorine acids	„	Chloracids.
„ Bromine acids	„	Bromacids.
„ Iodine acids	„	Iodacids.
„ Fluorine acids	„	Fluacids.
„ Cyanogen acids	„	Cyanacids.
„ Sulphur acids	„	Sulphacids.
„ Selenium acids,	„	Selenacids.
„ Tellurium acids	„	Telluracids.

859. The acids formed by oxygen received their names, for the most part, before the basacigen bodies were recognised as elements, or the existence of some of them discovered. Hence, in the case of the oxacids, it is neither customary nor expedient, to prefix any syllables indicating their basacigen ingredient. Consequently, we have sulphuric, selenic, telluric, chloric, bromic, iodic, &c. &c. instead of oxysulphuric, oxyselenic, oxytelluric, oxychloric, oxybromic, oxiodic, &c. The syllables were employed prior to the recognition of the elementary character of chlorine, to designate an oxacid with an extra proportion of oxygen. Thus chlorine was

think, be advantageously abbreviated into oxacids, chloracids, bromacids, iodacids, fluacids, cyanacids, sulphacids, selenacids, telluracids.

“I had formed my opinions on this subject before I was aware that Dr. Thomson had resorted to this classification.

“As respects the acids individually, I conceive that it would be preferable, if the syllable indicating the more electro-negative element had precedency in all, as it has in some cases. The word hydrofluoric does not harmonize with fluoboric, fluosilicic, fluochromic, fluomolybdic, &c. Fluorine being in each compound the electro-negative principle, the syllables, indicating its presence, should in each name occupy the same station. These remarks will apply in the case of acids formed with hydrogen by all principles which are more electro-negative. Hence we should use the terms chlorohydric, bromohydric, iodohydric, fluohydric, cyanhydric, instead of hydrochloric, hydrobromic, hydriodic, hydrofluoric, hydrocyanic.

“As by the British chemists the objectionable words have not been definitively adopted, the appellations muriatic and prussic being still much employed, it may not be inconvenient to them to introduce those which are recommended by consistency. In accordance with the premises, the acids formed with hydrogen by sulphur, selenium, and tellurium, would be called severally sulphydric, selenhydric, and telluhydric acid. Compounds formed by the union of the acids, thus designated, with the bases severally generated by the same electro-negative principles, would be called sulphydricates, selenhydricates, and telluhydricates, which are the names given to these compounds in the Berzelian nomenclature. Influenced by the analogy, a student would expect the electro-negative ingredient of a sulphydric acid to be sulphydric acid, not a sulphide. The terminating syllable of this word, by its associations, can only convey the conception of an electro-positive compound.”

miscalled oxy muriatic acid, being supposed to be an oxide of an unknown radical, with an extra dose of oxygen. (888.) At this time, oxychloric acid designates the acid which has more oxygen than the chloric acid.

860. The analogy between the acids formed by hydrogen with the halogen bodies, chlorine, bromine, iodine, fluorine, and cyanogen, render it both desirable and practicable to treat of them in a body, mainly by reference to chlorohydric acid. Hence I shall employ the word *halohydric*, to designate those acid compounds; and in obedience to similar considerations, the compounds formed with hydrogen by the amphigen bodies, sulphur, selenium, and tellurium, will be designated as *amphydric* acids.

861. The compound formed by the union of hydrogen with oxygen, the protoxide of hydrogen, (water,) ought not to be included under the head of the amphydric acids. Of this oxide, the pretensions to the characteristics of a base, are at least as high as those which can be advanced for it as an acid. Of course it cannot, with propriety, be classed with any *acid* compounds. It is in reality an anomalous substance, performing a part in nature of such pre-eminent importance, as to merit to a certain extent an isolated position, and undivided attention.

862. *Names of the halohydric acids, or those formed by the five halogen bodies, chlorine, bromine, iodine, fluorine and cyanogen, with hydrogen, as heretofore given by the French chemists, also by Berzelius, Turner, and others, contrasted with those now employed in this Compendium, agreeably to the practice of Thenard, and with the approbation of Berzelius.\**

For hydrochloric	use	chlorohydric.
„ hydrobromic	„	bromohydric.
„ hydroiodic	„	iodohydric.
„ hydrofluoric	„	fluohydric.
„ hydrocyanic	„	cyanohydric.

863. *Names of the amphydric acids, or acids formed by the amphigen bodies of Berzelius (excepting oxygen) with hydrogen.*

For hydrosulphuric	use	sulphydric.
„ hydroselenic	„	selenhydric.
„ hydrotelluric	„	telluhydric.

\* I cheerfully admit that it would be preferable to employ the word chlorohydric, instead of hydrochloric. My motive for retaining this last, was, that I was unwilling to venture upon a new nomenclature in a language foreign to me, in which it was inexpedient to make changes which could be avoided without inconvenience. I also agree with you, that we ought not to use combustible and oxidable, as having the same meaning. I have deserved your strictures for this inconsistency in my language; but I must suggest as an apology, that the two words were formerly used as synonyms, and that the work, in which you have recently noticed this oversight, was first published in 1806, having been from time to time remoulded for new editions, without its having been possible to eradicate all that has not kept pace with the progress of science.

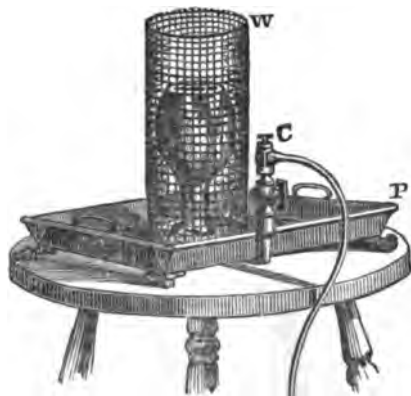
## COMPOUND OF HYDROGEN WITH CHLORINE.

*Of Chlorohydric or Muriatic Acid Gas.*

864. When hydrogen and chlorine are mixed in equal volumes they combine spontaneously. In the dark, or where the light is feeble, the union is slowly accomplished but, in the solar rays, takes place explosively. According to Silliman, the direct rays of the sun are not necessary to produce the result. The mixture may also be exploded by the electric spark, or by contact with any ignited matter. However the union may be effected, chlorohydric or muriatic acid gas is produced, without any reduction of volume if no water be present.

*Synthesis of Chlorohydric Acid Gas.*

865. In order to demonstrate the ratio in which chlorine and hydrogen combine, it is only necessary to introduce and ignite in the volumescop over water, equal measures of each gas. If they be pure, there will be a complete condensation. The experiment is conducted precisely as in the case of oxygen and hydrogen, excepting that in lieu of a half volume of oxygen, a volume of chlorine is supplied from a self-regulating reservoir. (798.)

*Explosive Reaction of Hydrogen with Chlorine, under the influence of the Solar Rays.*

866. A flask is half filled with chlorine over the pneumatic cistern in the usual way, and then transferred to the pan P, so as to have its orifice exactly over that of a pipe which, at the other end, communicates with the cock C, to which is annexed a flexible pipe extending to a self-regulating reservoir of hydrogen. (799.)

867. The flask is surrounded by a wire gauze, W, and just before the explosion is desired, hydrogen from the reservoir is allowed to occupy that portion of the cavity which was previously unoccupied by the chlorine. It

should be understood that the pan, during this operation, retains a sufficient stratum of water to cover the mouth of the flask, and that this is occupied with the same liquid in part until it is displaced by the hydrogen.

868. The preliminary arrangements being made, a mirror must be placed

in a situation to receive the solar rays without passing through window glass, and to reflect them upon the flask. The result is an explosion, from the effects of which the spectators are protected by the wire-gauze.

869. It must be obvious that this experiment can only succeed when the sun is unobscured.

870. It should be understood that the condensation arises altogether from the absorption of the gas by the water. (866.)

### *Preparation of Chlorohydric or Muriatic Acid Gas.*



871. Into a tubulated retort, introduce about as much chloride of sodium (common salt) as will occupy nearly one-third of the body, A. Lute a glass funnel, furnished with a cock, into the tubulure. Let the orifice of the beak, B, be so depressed below the surface of the mercury in the cistern, as to be under a bell glass, filled with, and inverted over, the mercury, and properly situated for receiving any gas which may escape through the beak. Prepare about three-fourths as much strong sulphuric acid by weight as there may be salt in the retort. After pouring about one-third of the acid into the retort, close the cock of the funnel: the mixture will rise in a foam, and a portion of gaseous matter will pass into the bell. As soon as the foam subsides, add more of the acid until the whole is introduced. Then as soon as the foam again subsides, apply the chauffer, C, and chlorohydric acid gas will continue to be copiously evolved. I have of late substituted for the funnel a glass tube of about a half an inch in bore at one end, tapering, at the other end, to an orifice of about the eighth of an inch in bore. This tube, being inserted into the retort through the tubulure, and luted thereto air-tight,

affords a channel for the gradual introduction of the acid which, surrounding the lower orifice of the tube, prevents the gas from escaping.

872. *Rationale of the Process.*—The water combining with the sulphuric acid is decomposed; its oxygen unites with the sodium, forming soda, with which the sulphuric acid combines, forming sulphate of soda. The hydrogen of the water and the chlorine escape as chlorohydric acid gas.

873. *Properties.*—Chlorohydric acid has all the attributes of a gas. It is colourless, and, although less active than chlorine gas, is to the organs of respiration intolerably irritating, and if not very dilute, deleterious to life. On escaping into the air, it produces white fumes, from its meeting with moisture. Its affinity for water is so great that this liquid will take up 420 times its bulk, and when in this state, ice is liquefied as if surrounded by fire. When brought into contact with the metals which decompose water, its hydrogen is liberated, while the chlorine unites with the metal. Equal weights of potassium separate the same weights and volumes of hydrogen from chlorohydric acid, and from water; a result conformable with the inferred atomic composition of both. Presented to metallic oxides, a reciprocal decomposition ensues; the hydrogen unites with the oxygen generating water, the chlorine with the metal producing a chloride. If mingled with oxygen and exposed to the action of heat or a succession of electric sparks, gaseous chlorohydric acid is partially decomposed. This result cannot be extended to more than  $\frac{1}{4}$ th of the whole volume. At the temperature of  $50^{\circ}$ , and under a pressure of forty atmospheres, it becomes a colourless liquid.

874. Its specific gravity is 1.2694, a mean between that of its constituents. The weight of 100 cubic inches is 39.36 grains.

One atom of chlorine, equivalent	36
And one atom of hydrogen, equivalent	1
	—
Constitute one atom of chlorohydric acid gas, equivalent	37



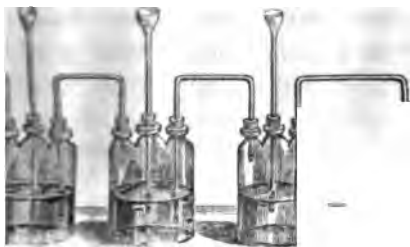
*Experimental Illustrations.*

Equal volumes of hydrogen and chlorine, being and subjected to the solar rays, (867,) or galvanic, (818,) explode and form chlorohydric acid gas.

Gas collected over mercury in tall jars. Water, d by litmus, being introduced, rapidly changes to a sur, and causes the disappearance of the gas. Same roduced by ice, which is rapidly melted.

*Preparation of Liquid Chlorohydric or Muriatic Acid.*

It may be obtained by saturating water with the Woulfe's apparatus. (See the following figure.) The is nearly pure in all the receptacles excepting the

*Woulfe's Apparatus.*

this figure Woulfe's apparatus is depicted in an improved form. The l in the retort, first passes into the globe where any vapour which may it condenses. It then proceeds along the tube which establishes a com- with the bottle next to the globe. As that mouth of this tube which is bottle, is below the surface of the liquid placed there to absorb it, the gas le up through the liquid, so as to promote its own absorption by the agi- induced. It then rises above the surface of the liquid, where a further takes place. The excess of gas, beyond the quantity absorbed by the li- first bottle, passes, by means of the connecting tube, to the second bottle, ver portion is not there absorbed, reaches the third bottle, in the case of process proceeds as in that of the first two. Should any of the gas escape series, it may, by lengthening the last tube, be conducted under a bell with water on the shelf of the hydro-pneumatic cistern, so as not to an- rator. But this never takes place in the case of chlorohydric acid gas, ater is nearly saturated.

posing the extrication of gas to cease before the liquid in the first bottle the absorption continuing, the liquid in the second bottle might be trans- e first, in consequence of the rarefaction of the residual gas rendering it a to resist the atmospheric pressure. In like manner the contents of the might be transferred to the second. To prevent these inconveniences, each bottle a straight tube fastened air-tight into an intermediate neck, dug into the liquid. By these means an adequate pressure is opposed e of the gas, and yet any diminution of pressure, arising from absorption, pensated by the ingress of atmospheric air, ere the liquid can be drawn e next bottle. To prevent absorption from the first bottle into the globe, use, for the introduction of the acid, a trumpet-mouthed tube of small g through and luted into the tubulure by a cork with lead and a gum age, and terminating in a small orifice near the bottom of the retort inside.

880. Of late I have resorted to the following expedient. The beaks of four tubulated retorts, are drawn out by heating them in a hole opened by a poker in an anthracite fire, until the beak, by its own weight, is made to extend itself into a long tapering tube. At the moment when this takes place, by lifting it from the fire and holding the body of the retort in a suitable position, the tapering portion of the beak hangs down, making the desired angle with the other part of the beak. Of course it retains this form when cold. The retorts thus prepared, are so associated that the beak of No. 1, the larger retort, may enter No. 2, through the tubulure of No. 2, and that the beak of this may in like manner reach into No. 3. Of course a fourth and a fifth retort may, if requisite, be thus made to communicate. The beaks are to be luted to the tubulures; and No. 1, being supplied with the salt, and furnished with a tapering tube for the introduction of the sulphuric acid, the process is to be conducted as already described. (873, &c.)

881. Commercial chlorohydric acid is so cheap, that I have found it preferable to use it in the first retort, instead of salt. The addition of sulphuric acid causes the gas to come over pure, without heat at first, but with the aid of a gentle heat, nearly the whole may be evolved, and of course absorbed by the water, placed purposely within retorts, No. 2 and 3. It is preferable to add a fourth retort, and to have No. 3 quite small, holding only a small quantity of water, just adequate to wash out of the gas any sulphuric acid which may attend it in the form of a spray. It may be remarked, that one advantage of this process is, that the iron which is usually an impurity in liquid chlorohydric acid, forms a compound with sulphuric acid, which is not like the chloride of that metal, volatile. Consequently, by this process, the acid is depurated of iron.

882. Liquid chlorohydric acid may also be obtained by distilling a solution of chloride of sodium in water with sulphuric acid. In this way there is no need of an apparatus for preventing absorption, as described in the preceding article. The acid comes over and condenses in union with the requisite quantity of water.

883. *Properties of the Liquid Chlorohydric Acid.*—When concentrated, it produces suffocating fumes from the escape of gas. When pure, it is colourless, though usually straw-coloured from the presence of a minute portion of iron.

884. Dr. Thomson informs us that the strongest liquid acid which he could obtain, consisted of one atom of acid, equivalent 37, united with six atoms of water, which being equivalent to 54, the proportion of acid to water by weight was as those numbers, or nearly as 2 to 3.\*

\* The relative equivalent proportion of chlorohydric acid and water, or proportion of said acid, by weight, in aqueous solutions of different specific gravities, may be learned from the following table. (See Thomson's Principles of Chemistry.)

Atoms of Acid.	Atoms of Water.	Real Acid in 100 of the Liquid.	Specific Gravity.
1	6	40.659	1.203
1	7	37.000	1.179
1	8	33.945	1.162
1	9	31.346	1.149
1	10	29.134	1.139
1	11	27.206	1.1285
1	12	25.517	1.1197
1	13	24.026	1.1127
1	14	22.700	1.1060
1	15	21.512	1.1008
1	16	20.442	1.0960
1	17	19.474	1.0902
1	18	18.590	1.0860
1	19	17.790	1.0820
1	20	17.051	1.0780

*Experimental Illustrations.*

liquid chlorohydric acid exhibited; also its reaction with other bodies.

*Theory of the Nature of Chlorine and Chlorohydric Acid.*

Chlorohydric acid was deemed to be a compound of oxygen with hydrogen radical. When distilled from red oxide of lead, or black manganese, it was supposed to combine with a portion of the oxygen, forming oxygenated muriatic acid, the name then being given. To the oxygen thus imagined to exist in it, the activity was ascribed as a supporter of combustion and as a solvent of metals, which has since been proved that neither carbon nor the metals are not intensely ignited in dry chlorine. The metals are converted into oxides, while the carbon undergoes no change. Chloride of sulphur and chloride of phosphorus, which result from saturating these substances with chlorine, are devoid of acidity; but the addition of water converts muriatic and phosphorous acid, the other into muriatic and phosphoric acid.

Chlorine being muriatic acid oxygenated, the discovery of the hypochlorous, chloric, and oxychloric acids must establish this anomaly of muriatic acid, by successive additions of the same principle, gains, loses, and regains acidity, forming first an acid, then a base, and finally four acids. I have said it forms an oxide, because it must be deemed an oxide, having no acid properties. As has been stated, page 156, that Thenard oxygenated the water in muriatic acid; yet this did not convert it into a solution of chlorine. According to the doctrine now universally sanctioned by chemists, muriatic acid, consisting of chlorine and hydrogen, is deprived of all those processes by which it was formerly supposed to be

*Of Bromohydric Acid.*

To obtain bromohydric acid, Berzelius recommends that phosphorus be placed in contact with bromine under water. The resulting gas is dissolved into phosphoric acid and bromohydric acid gas. The gas is collected over mercury, or made to produce liquid bromohydric acid by union with water, exactly by the same means as have been illustrated in the case of chlorohydric acid, which the bromohydric acid much resembles. Bromohydric acid is a colourless gas, in smell similar to chlorohydric. It has a specific gravity of 2.7353. When brought in contact with air it produces thick fumes. It is decomposed in passing over red-hot iron. It is composed of one atom of hydrogen and one of bromine.

*Of Iodohydric Acid.*

According to Berzelius, in order to procure iodohydric acid, nine parts of phosphorus should be placed in contact at the bottom of a small matrass, and protected from the air by powdered charcoal. Phosphoric acid is formed, which is resolved into phosphoric acid and iodohydric acid gas by the gradual affusion of a small quantity of water. The gas cannot be collected over water or mercury, as it acts on

the one and is absorbed by the other. They are collected in bottles, by means of tubes descending through their orifices to their bottoms, which is analogous to the mode already illustrated on a large scale, for collecting chlorine. (666.) This process is even more practicable in the case in point; since iodo-hydric acid is the heaviest gas known, having a specific gravity of 4.3854, or more than four times as great as that of atmospheric air. In composition and general properties it resembles chlorohydric and bromohydric acid.

892. The compound of hydrogen with fluorine, forming the acid of fluor spar or *fluohydric acid*, improperly called hydrofluoric acid, will be deferred for consideration, until boron and silicon have been treated of.

#### COMPOUNDS OF HYDROGEN WITH SULPHUR.

893. It appears probable that hydrogen and sulphur may combine in various proportions. Only two compounds, however, have been sufficiently distinguished, to be worthy of a place in this work. One of these is a definite compound of hydrogen and sulphur, containing an atom of each, and has hitherto been called sulphuretted hydrogen, especially by the British chemists. The other contains one atom of hydrogen, with a plurality of atoms of sulphur, which, according to Thenard, may extend to the proportions of four, six, or eight atoms to one. To this he has accordingly given the name of polysulphuret of hydrogen.

894. Pursuant to the nomenclature of Berzelius, all the electro-negative compounds of sulphur are called sulphides, and are designated by attaching, as an adjective, their radical, with the last syllable changed into *ique* in French, or *ic* in English; as, for instance, sulphuretted hydrogen is called by him in French, *sulphide hydrique*, which in English is rendered by *hydric sulphide*. This gas has by some chemists, especially the French, been called hydrosulphuric acid, by analogy with hydrochloric acid. The term *hydrosulphuric* is objectionable from its conveying the idea of aqueous sulphuric acid; *hydro* being used to imply the presence or influence of water. I have already pointed out the inconsistency of designating some acids by giving precedence to the syllables representing their radical, as in hydrochloric, hydriodic; while in others, the syllable indicative of their electro-negative ingredient has the precedence, as in fluosilicic, fluoboric, chlorocarbonic, and chlorocyanic. If sulphuretted hydrogen is to receive a new name, I would prefer to call it *sulphydric acid*, as already suggested. (858, &c.)

### *Of Sulphydric Acid or Sulphuretted Hydrogen.*


895. Few persons are unacquainted with the unpleasant odour which results from the washings of a gun barrel, made foul by the explosion of gunpowder, or that produced by putrid eggs. This odour arises from a compound consisting of one atom of hydrogen and one atom of sulphur. The celebrated sulphur springs of Virginia are indebted for their odour, and mainly for their efficacy, to this compound; to which the celebrated Thenard has given the name of sulphydric acid.

896. *Preparation.*—This gas is copiously evolved by the reaction of diluted sulphuric acid with sulphuret of iron. In order to have a supply of it at command, it is only necessary to substitute this last mentioned substance for zinc in the self-regulating apparatus employed for hydrogen, already described. (706.)

897. As it is absorbed by water and gradually decomposed by mercury, Berzelius recommends that it should be received over brine. Its purity is demonstrated by its complete absorption by a solution of caustic potash, and by its not rendering lime-water milky.

898. He also advises that the gas should be passed through water, as otherwise it is liable to be contaminated by the generating materials. When the acid is sufficiently diluted, the action in the apparatus above referred to is so gentle, that I am confident from my experience that the gas comes over sufficiently pure for ordinary purposes.

#### *Convenient Method of impregnating Liquids with Sulphydric Acid.*



Suppose the little flask, F, to contain the liquid to be impregnated, and the flexible pipe, one end of which is inserted into the orifice of the flask, to proceed from a self-regulating reservoir of sulphydric acid: it must be evident that the gas, flowing into the cavity of the flask from the orifice of the pipe, must enter the solution. If not absorbed as rapidly as it may be yielded, the excess must bubble up through the solution; the cork being meanwhile loosened to allow the atmospheric air to escape. The expulsion of the atmospheric air having been completed, and the cork inserted into the neck of the flask, so as to prevent the gas from escaping, it will continue to enter the flask as fast as absorbed. But if it be generated in the reservoir more rapidly than the solution can absorb it, the excess must remain in the reservoir, and contribute to depress the acid so low in the bell-glass, as to diminish the quantity of the sulphide on which it can act. Finally, when the solution becomes saturated, the gas generated in the bell must fill it, and thus, by usurping the place of the acid, cause its reaction with the sulphide of iron to be suspended.

900. *Properties.*—Sulphydric acid is a permanent gas with the odour of rotten eggs, absorbable by water, inflammable and explosive, forming, by combustion with air, oxygen gas, water, and a mixture of sulphurous and sulphuric acids.

901. At the temperature of  $50^{\circ}$  F., and under a pressure of 17 atmospheres, sulphydric acid becomes a colourless liquid more fluid even than sulphuric ether.

902. Metals are tarnished by it, especially preparations of lead, of which it is a test, and by which it may be detected. It is evolved from privies, blackening the ceruse or carbonate of lead in paint. It may be decomposed by various substances, having an affinity for one or both of its constituents, as for instance, by chlorine, potassium, sodium, sulphurous acid, and ignited carbon; also by successive electric explosions.

903. Sulphydric acid decomposes all metallic solutions, except those of cobalt, nickel, iron, zinc, manganese, titanium and molybdenum, in consequence of the attraction between hydrogen and either oxygen or chlorine, and between the metals and sulphur. Metals, which in the metallic state yield hydrogen during their reaction with diluted sulphuric or muriatic acid, afford sulphydric acid, when in the state of a sulphide or sulphuret, subjected to those acids. According to Berzelius, some sulphides act as acids, others as bases, and unite with each other in a manner analogous to that in which the oxacids and oxybases combine. The resulting compounds he calls sulpho-salts. Some sulphides are liable to be reduced by exposure to pure hydrogen in a way analogous to that in which oxides are decomposed by the same agent. But the number of sulphides which may be thus decomposed is much smaller. Atmospheric air is said to be rendered deleterious to life by the addition of  $\frac{1}{100}$ th of this gas.

904. It is alleged that a single cubic inch of the gas liberated in a large chamber, will in every part be productive of its characteristic unpleasant odour. A current of the gas directed upon the tongue causes an astringent acid, and bitter taste. The specific gravity of sulphydric acid is 1.1782, that of atmospheric air being 1. It is slowly decomposed by nitric oxide, and by sulphurous acid when moist. Nitroso-nitric acid reacts with it explosively. With sulphurous acid when dry it does not react;

being present, condensation ensues with a deposition of sulphur, and, according to Thompson, the production of sulphuric acid. At the temperature of 50° F., water takes sixteen times its bulk of sulphydric acid, which may be expelled by a boiling heat. The aqueous solution turns litmus, and becomes turbid after some time by exposure to the air, with the oxygen of which the hydrogen gas combines, while the sulphur precipitates. It has been stated that water impregnated with sulphydric acid exists in many natural springs, which are much benefited by invalids.

The celebrated white sulphur, salt sulphur, and red sulphurs of Virginia, are of this nature. They are particularly efficacious as remedies for bilious disorders in cutaneous diseases.

The red sulphur springs are thought to be peculiarly useful in some pulmonary complaints, and appear to exert a surprising and unaccountable influence in lowering febrile activity and force of the pulse.

### *Experimental Illustrations.*

**Method of extricating sulphydric acid gas by means of a self-regulating reservoir exhibited; also, the action of water with it. Effects of its aqueous solution on litmus, and on various metallic solutions. Characters written with dissolved acetate of lead are blackened by exposure to the gas, or its aqueous solution. Its action on nitric acid.**

#### *Sympathetic Picture.*

The original of this figure (see the engraving at the top of the following page) was drawn of a gigantic size, in acetate of lead, and was invisible at a little distance until a jet of sulphuretted hydrogen was directed upon it. The image was rendered visible by the waving of the pipe from which the gas flowed, as if it were the wand of a magician.

If the acetate has had time to become dry, the experiment will not succeed unless a due degree of moisture. This object is best accomplished by holding a wet sponge over the back of the sheet on which the figure has been drawn.

**Analysis.**—The acetate of lead consists of acetic acid and oxide of lead. When exposed to the gas, a portion of the oxide unites with the hydrogen of the gas, while the sulphur forms a sulphuret, to which the blackness of the picture is due.



### *Of the Polysulphide of Hydrogen.*

911. There are various compounds formed by sulphur with metals of which are soluble; as for instance the compound formed by boron with lime. This compound has been called a persulphuret of calcium; I would call it a persulphide. Scheele ascertained that on pouring indurated acid a persulphuret, such as that to which I have alluded, a looking liquid was precipitated, which subsequently received the name of bisulphuretted hydrogen. Thenard designates this compound as the *sulphuret of hydrogen*, on account of the great and variable number of atoms of sulphur which enter into its composition. Moreover he states that it constitutes a compound analogous in its properties to the deuterohydrogen; being like that mysterious combination decomposable by many substances for which it has no affinity. Even the presence of the persulphide employed in its production is incompatible with its existence; hence the impossibility of forming it by pouring the acid into the solution. In that case an excess of the persulphide must inevitably be present.

912. He alleges that the polysulphuret (polysulphide) is always formed at ordinary temperatures. Its colour is yellow, sometimes approaching greenish-brown. It whitens the tongue when applied to it, as is the case upon making a similar application of deutoxide of hydrogen. The same effect is produced upon the skin. Litmus paper is bleached by it, especially when it is diffused in muriatic acid. Sometimes it has the consistency of an essential oil, sometimes of a fat oil, according to the proportion of its constituents, which has already been stated to be variable. Its odour is peculiar and disagreeable, especially at the period when, having been recently formed, the supernatant liquid is decanted from it.



also it affects the eyes painfully. Sooner or later it is resolved into its elements spontaneously. Charcoal, platinum, gold, iridium, and many other metals in the pulverulent form, cause the evolution of the hydrogen. Many metallic oxides have the same effect, some so actively as to cause a brisk effervescence. These results also ensue from contact with the deut-oxide or bioxide of manganese, from magnesia, from silica, and above all from pulverized baryta, strontia, lime, potash, and soda. From some of the facts mentioned by Thenard, I infer that this substance may be of great service in bleaching.

## COMPOUNDS OF HYDROGEN WITH SELENIUM AND TELLURIUM.

### *Of Selenhydic Acid, commonly called Selenuretted Hydrogen.*

913. Selenhydic acid is supposed to consist of one atom of selenium, and one atom of hydrogen. It may be obtained from the selenide of potassium or of iron, by the action of chlorohydric acid. It is a colourless gas, soluble without change of colour by water which has been boiled. Water so impregnated has an hepatic taste, reddens litmus paper, and if applied to the skin, stains it a brownish-red. The solution exposed to the air, by oxidation of the hydrogen, becomes gradually turbid from the surface inwards, acquiring a reddish hue, and depositing selenium in light flocks. Metallic salts, even those of iron and zinc, when they are neutral, are precipitated by selenhydic acid. The precipitates are generally of a deep black colour, yet those of zinc, manganese, and cerium, are flesh-coloured. By the oxidization of the hydrogen in selenhydic acid, selenium is precipitated of a cinnabar-red colour on any moist body. This acid exercises upon the respiratory organs a violent action, which might easily become dangerous. It produces at first the odour of sulphydric acid, but soon after prickling sensation in the membranes of the nostrils, which resembles that caused by fluosilicic acid gas, but is more stimulating. Subsequently the eyes become red, and the sense of smell is paralyzed. A single bubble of the gas, received into the nose, caused such a paralysis of the olfactory nerves, as to create insensibility even to the fumes of the strongest ammonia. The power of detecting odours was not recovered before the expiration of five or six hours.

914. Thenard mentions that Berzelius, in consequence of inhaling selenhydic acid gas, was attacked by a cough so severe, that a blister was deemed necessary. The quantity inhaled was so minute as to give the impression, that, in its effects upon the human system, this gas is presently pernicious.

### *Of Telluhydic Acid, commonly called Telluretted Hydrogen.*

915. When an alloy of tellurium with zinc or tin is exposed to the action of chlorohydric acid, telluhydic acid is evolved. It is a colourless gas, which strongly resembles sulphydric acid in smell and in its chemical and physical properties. It reddens litmus paper, is soluble in water, producing a colourless solution, which by exposure to the air becomes brown, in consequence of the oxidation of the hydrogen and precipitation of the selenium. It is probably composed of one atom of hydrogen and one of selenium.

916. The effect of the monosyllable *gen*, in chemical language, has been explained. (See note, 628.)

## SECTION II.

### OF NITROGEN OR AZOTE.

917. In the gaseous state, it forms nearly four-fifths of the atmosphere in bulk. Its ponderable base is a principal element in animal substances. In vegetables, it is occasionally found. It was called azote, from the Greek *ζωη*, life, and *α*, privative of. It was subsequently named nitrogen, azote being equally applicable to other gases which are destructive of life. I regret that Thenard, instead of abandoning the use of this bad word, has lately endeavoured to give it a further hold on nomenclature, by using the words azotous and azotic, in lieu of nitrous and nitric.

918. Consistently with the explanation which has been given of the monosyllable *gen*, *nitrogen* signifies a capacity to produce nitric acid, as oxygen conveys the idea of capacity to produce acids generally.

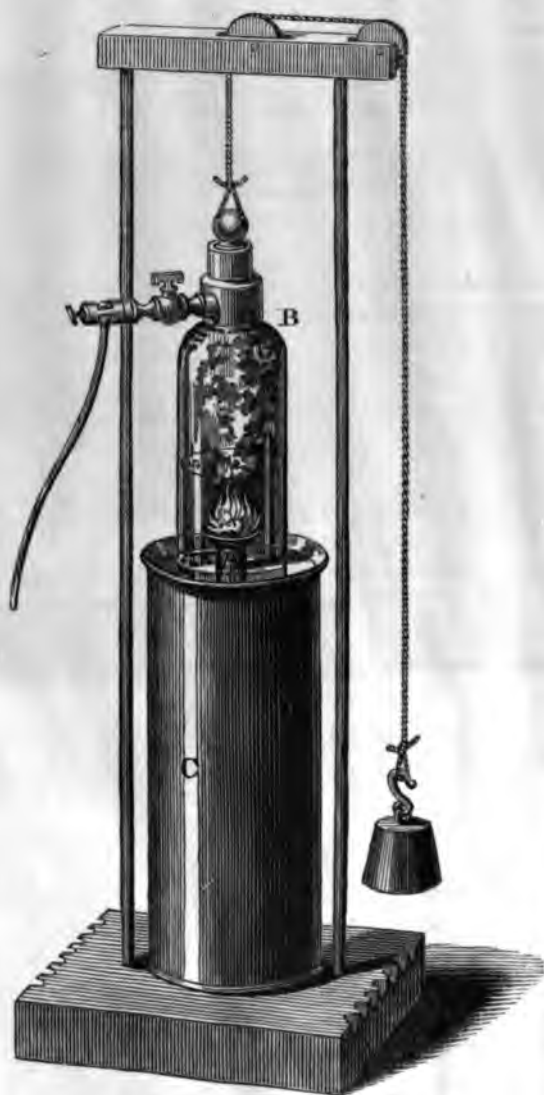
919. *Preparation.*—Nitrogen may be procured by the aid of any substance which will, in a close vessel, abstract oxygen from the included portion of the atmosphere; for instance, by the combustion of phosphorus, or by iron filings and sulphur moistened. This gas may also be obtained by heating muscular flesh in a retort with nitric acid very much diluted. When obtained by means of phosphorus, a minute quantity of this substance remains in solution in the nitrogen; when extricated by the action of nitric acid, it contains a small portion of carbonic acid. In either case it may be purified by washing it with an alkaline solution, or with lime-water.

920. Another method of obtaining nitrogen gas is to pass chlorine through liquid ammonia. The chlorine unites with the hydrogen of the ammonia, while the nitrogen is liberated. Care must be taken to have the ammonia in excess, otherwise a chloride of nitrogen may be formed which is capable of producing the most violent explosions.

921. When the chlorite of lime (bleaching salt) is mixed



*Abstraction of Oxygen from Atmospheric Air by Phosphorus.*



gled with muriate of ammonia and moistened, nitrogen is evolved. For this purpose Professor Emmet has recommended the boiling of nitrate of ammonia upon zinc.

*Apparatus for obtaining the Nitrogen from Atmospheric Air.*

922. The apparatus represented in the opposite engraving leaves the nitrogen so situated, as to be drawn easily from the containing vessel, in such quantities and at such times as may be desirable. In its principal parts, it does not differ from the gasometer for oxygen. (617.) It is provided with a pipe, *p*, concentric with the axis of the lower vessel, *C*, surmounted by a small copper cup. The pipe in question descends perpendicularly from the level of the brim of the vessel to the bottom; being soldered into a hole in the latter, so that, the bore being accessible from without, the copper cup at the upper end may, when necessary, be touched with the end of a red-hot iron rod, introduced through the pipe as in burning phosphorus in oxygen. (614. &c.)

923. The inner vessel of the gasometer consists of a bell-glass, *B*, suspended by a cord passing over a wooden gallows with suitable pulleys. The bell has a perforated neck cemented into a brass cap, furnished with a female screw for receiving a cock. To this cock a flexible lead-pipe is attached by a gallows screw. Upon the copper cap a sufficient quantity of phosphorus being placed, and the lower vessel adequately supplied with water, the bell-glass is suspended within the lower vessel, as is usual with gasometers, and allowed to descend about a third of its depth. Meanwhile, the cock of the tube being open, the air is allowed to escape, so that the liquid within and without the bell-glass may be on a level. The cock being in the next place closed, and the temperature of the phosphorus sufficiently raised to make it take fire by touching the cup with the extremity of an iron rod previously reddened in the fire, a brilliant combustion ensues. As soon as it declines, the iron, meanwhile kept in the fire, should be again introduced, in order to sustain the combustion till all the oxygen is absorbed.

924. When the air in the bell-glass is completely deoxidized, which may be known by the fumes becoming yellow, the residual nitrogen may be expelled into any recipient at pleasure, through the flexible pipe attached to the cock for that purpose, by depressing the bell in the water.

925. *Properties of Nitrogen Gas.*—As a gas, it is distinguished by a comparative want of properties. It is lighter than oxygen gas, or atmospheric air. It supports neither life nor combustion, but is obviously a harmless ingredient in the air.

926. The affinity of nitrogen for caloric, compared with that which it displays for other substances, appears to be peculiarly great. Hence it is not liable, like hydrogen or oxygen, to enter into combination with other matter, so as to part with the caloric to which it owes its existence as a gas; and when under any circumstances it does enter into combination, it seems, more than almost any other substance, to carry caloric into combination with it; being, consequently, an ingredient in a majority of the most powerful fulminating compounds.

927. Nitrogen has been suspected by some chemists to be a compound, but is generally considered as an element. At the temperature of 60° F., 100 cubic inches weigh

30.1650 grains. Its specific gravity, comparatively with air, is 0.9727.

*Experimental Illustrations of the Properties of Nitrogen Gas.*

928. A portion of the nitrogen, obtained as above described, being introduced into a bottle, extinguishes a candle flame when introduced into it; but being mixed with one-fourth of its bulk of oxygen gas, the effect of the mixture in supporting flame is similar to that of atmospheric air.

OF ATMOSPHERIC AIR.

929. Atmospheric air is a mixture, not a chemical compound, of oxygen and nitrogen gas, with some moisture and carbonic acid, in the following proportions.

	By Measure.		By Weight.	
Nitrogen gas	-	77.5	-	75.55
Oxygen gas	-	21.	-	23.32
Aqueous vapour	-	1.42	-	1.03
Carbonic acid	-	0.08	-	0.10
		<hr/> 100.00		<hr/> 100.00

930. The average of a great number of experiments made with my eudiometers, makes the proportion of oxygen 20.66 in 100 of air.

931. In addition to these constituents, it is alleged that there is a little chlorohydric acid in the atmosphere, in situations in the neighbourhood of the sea; and hence it arises, probably, that animals far inland, show a much greater avidity for common salt, a compound of chlorine and sodium, than those existing in regions bordering on the ocean. This avidity seems to have been implanted in order to supply a source for the chlorohydric acid, which appears to be requisite to the powers of the gastric fluid.

932. It has been made a question whether the nitrogen and oxygen of the air are not in a state of chemical combination. I am of opinion that no other cause of union between them exists than that which is known to produce the equable diffusion of heterogeneous gaseous particles among each other, notwithstanding the difference of the specific gravities.

33. In its qualities atmospheric air does not differ from mixture. Oxygen, mingled with hydrogen in the same portion in which it is mingled with nitrogen in the air, been found to support animal life nearly as well.

34. The mechanical influence of the atmosphere, so far appertains to chemistry, has been sufficiently illustrated, (177, &c.) I have also treated of its capacity to moisture, and to promote and produce cold by evaporation, (229, &c.) Some additional methods of analysis, will be mentioned under the heads of nitric oxide and phosphorus.

#### *Eudiometrical Analysis of the Atmosphere.*

1. While on the subject of atmospheric air, the eudiometrical analysis becomes necessarily an object of attention. I have already given an outline and description of a large eudiometer, which I have designated volumecope. By means of that instrument it was demonstrated, that the elements of water are mixed in the gaseous state and ignited, will always combine in the proportion of two volumes of hydrogen to one of oxygen. It follows that, if any gaseous mixture containing hydrogen, and no other gas capable of combining with hydrogen or oxygen, mixed with an excess of hydrogen, all the oxygen will be condensed into water, and may be estimated as equal to one-third of the resulting deficit. It follows also that, if, to a gaseous mixture containing hydrogen, and no other gas with which hydrogen or oxygen can combine, an excess of oxygen be added and the mixture ignited, all the hydrogen will be condensed, and will in quantity equal two-thirds of the deficit. Thus, if five volumes of atmospheric air and three of hydrogen be introduced into the volumecope and ignited, the eight volumes will be reduced to rather less than five; and a little more than three volumes will have been condensed, of which one-third is oxygen. In five volumes of atmospheric air, there is, therefore, somewhat more than one volume of oxygen. By the volumecope the excess cannot be accurately measured, but by other instruments which I have contrived, and which I shall proceed to describe, great accuracy is attainable. I am the more particular in describing my apparatus in this preface, that I may not be under the necessity of occupying the time allotted to my lectures with such descriptions.

#### *Of the Sliding-rod Eudiometer.*

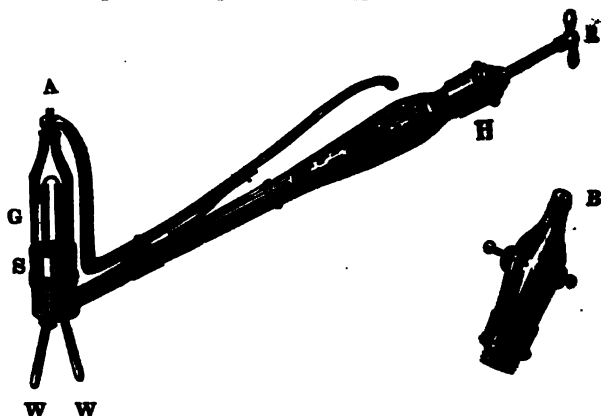
1. I have constructed some eudiometers, and gas measures, in which the measurement of gas is effected by a graduated rod, which slides into or out of the cavity of a tube, through a collar of leathers soaked in lard, and secured by a screw so as to be perfectly air-tight. This rod is employed to vary the capacity of the tube, and at the same time to be a measure of the quantity of air, or of any other gas, consequently drawn in or out. About one-third of the tube is occupied by the sliding-rod. The tube, being recurved, and converging to a perforated apex, is of a form adapted for withdrawing measured portions of gas from vessels inverted in water or mercury.

2. There were two forms of the sliding-rod eudiometer; one designed

to be used for explosive mixtures, requiring ignition; the other is independent upon the absorbing power of a liquid or gas. The former is from the eudiometers employed by European chemists, in the combustion for igniting the explosive mixtures, as well as in that for measuring galvanic ignition (335) being substituted for the electric spark.

938. I shall proceed to describe a sliding-rod eudiometer, for the analysis of explosive mixtures, which I designate as aqueous, because water is the confining liquid employed in it.

*Aqueous Sliding-rod Hydro-oxygen Eudiometer.*



939. This cut represents a hydro-oxygen eudiometer, in which the measures are made by a sliding-rod, and the explosions are effected by the galvanic ign of a platinum wire.

940. In the instrument represented by the preceding cut, the igniting wire is soldered into the summits of the two brass wires, W W, which pass through the h of the socket S, parallel to the axis of the glass recipient, G, within which the seen. One of the wires is soldered to the socket. The other is fastened by a of a collar of leathers, packed by a screw, so that it has no metallic communication with the other wire, except through the filament of platinum, by which they are bly connected above, and which I have already called the igniting wire. The has a capillary orifice at the apex, A, which is closed by means of a lever and a (apparent in the drawing,) excepting when the pressure of the spring is coe acted by the thumb of the operator. The sliding-rod, R, is accurately graduated about 160 degrees.

941. Experience has shown the expediency of securing the valve which closes aperture in the apex of the instrument from the possibility of leakage during a sions, by means of an iron staple with a screw, represented by the following



This fastens upon two pivots, one of which is inserted on each of the brass socket, S, into which the glass recipient, G, is coe ed. The staple hinges upon these pivots, and may be brought a position in which the screw, A, being immediately over the v may be made to tighten it; or the staple may be made to hang d so as not to be in the way when the instrument is to be cha In order to use the eudiometer, it must be full of water, free air-bubbles, and previously proved air-tight;\* the rod being troduced to its hilt, and the capillary orifice open, in conse of a due degree of pressure on the lever, by which it is c closed. Being thus prepared to ascertain the proportion of as in the air, draw the rod out of the tube till 100 graduations are ble. A bulk of air, equivalent to the portion of the rod thus

\* To prepare the instrument and prove it to be in order, depress the glass rod below the surface of the water in the pneumatic cistern, the capillary orifice



of course enter at the capillary opening; after which the lever must be closed. Introduce the receiver into a bell glass of hydrogen, and, open, draw out the rod as far as an enlargement upon the end will allow it to act. This arrestation will take place just as the 160th graduation becomes and then, in addition to the 100 measures of air previously taken, 60 of hydrogen have entered; next close the orifice, and withdraw the instrument from

Apply the projecting wires, *W W*, severally to the metallic cups, coming with the poles of the calorimeter represented below; then move the as to cause the receptacle holding the acid to rise about the plates. By frequent ignition of the wire, the gas will explode. The instrument being again into the water of the pneumatic cistern, so that the capillary orifice, closed, may be just below the surface, the water will enter and fill up the void by the condensation of the gases. The residual air being excluded by the portion of the rod remaining without the tube, will be in bulk equivalent, which may consequently be ascertained by inspecting the graduations performed this experiment in thirty seconds.

oxygen is to be examined by hydrogen, or hydrogen by oxygen, we must have a portion of each in vessels over the pneumatic cistern, and success the requisite quantities of them, and proceed as in the case of atmos-

other and perhaps more accurate mode of operating with this instrument is of one of the volumeters, (see 947, 953,) to make a mixture of the different in due proportion, in a bell glass. Thus, let two measures of atmosphere added to one of hydrogen; then on taking one hundred and fifty measures of mixture into the eudiometer, there will be the same quantity of each gas, as measures of hydrogen and 100 of air had been taken, as above described. In ascertain the quantity of pure oxygen in the gas from nitre or manganese, are of it might be added to three of hydrogen. Then of 160 measures of gas, which might be taken into the eudiometer, 40 would consist of the gas freed, and 120 of hydrogen; and one-third of the deficit, caused by the explosion, would be the quantity of pure oxygen in the 40 measures.

hydrogen were to be assayed, as, for instance, the gas evolved by the reacted sulphuric acid with zinc, (see page 144,) it would be proper to take parts of the hydrogen and oxygen; as the gas which is not to be analyzed are be in excess. Taking then 160 measures into the eudiometer, two-thirds the deficit, caused by the explosion, would be the pure hydrogen in 80 of the gas under analysis. For the last mentioned process it is preferable upon the rod, in addition to the scale of 160 (942), another of 200 degrees, means fifty measures of oxygen, or 100 measures of hydrogen, may be analyzed this way the per centage of impurity may be more readily perceived.

(see the preceding figure) represents a glass with wires inserted through tubes, in the usual mode for passing the electric spark, should this method of ignition be deemed desirable, for the sake of varying the experiment, purpose of illustration. This glass, the other being removed, may be fastened in the same place. The wires *W W*, may remain, but should be of such a sort to interfere with the passage of the electric spark. The instrument is used, as usual, excepting the employment of an electrical machine, or electricity, to ignite the gaseous mixture. For the travelling chemist, the last men-

tioned and open; draw the rod out of its tube and return it alternately, so that, by the action, a portion of water may pass in, and a portion of air may pass out. In operation, the instrument should be occasionally held in such a posture, that the air may rise into the glass recipient, without which its expulsion by the action of the rod is impracticable. Now close the orifice at the apex, *A*, and draw a few inches of the rod, in order to see whether any air can enter at the orifice or pass between the collar of leathers and the sliding rod. If the instrument is airtight, the bubbles, extricated in consequence of the vacuum produced by withdrawing the rod, will disappear when it is restored to its place.

The figure represents a calorimeter, containing two galvanic pairs, each consisting of plates of zinc and three of copper, severally eight inches by nine, for a description of which, see my Treatise of Galvanism or Voltaic Electricity. The wires, *W W*, of the eudiometer are forcibly pressed by one hand upon the metallic cups, in two masses of soft solder which constitute the poles of the instrument, the wires, *W W*, of the eudiometer are forcibly pressed by one hand upon the metallic cups, while by the other the acid is made to act upon the plates through the metal of the lever. Instantaneously on the ignition taking place, the action should be interrupted by lifting the eudiometer; as otherwise the wire might

tioned mode of ignition may be preferable; because an electrophorus is more reliable than a galvanic apparatus.

946. In damp weather, or in a laboratory where there is a pneumatic current, the moisture arising from the respiration of a large class, it is often difficult to accomplish explosions by electricity.

#### *Sliding-rod Gas Measure.*

947. The construction of this instrument, represented by the opposite of that of the sliding-rod eudiometers, in having a valve which is closed and shut by a spring and lever, acting upon a rod passing through a leather. By means of this valve, any gas drawn into the receiver, is inclined to be free from the possibility of loss, during its transfer from one vessel to another. This instrument is much larger than the sliding-rod eudiometers for mixtures; being intended to make mixtures of gas, in those cases where the proportions be to the other, in a proportion which cannot be conveniently obtained by more or less volumes of the one than of the other, by means of the volumeter (954), for instance, suppose it were an object to analyze the air according to Lavoisier's plan of taking 42 per cent. of hydrogen. The only way of mixing the hydrogen in such a ratio, would be to take the full of the volumeter 21 times of hydrogen, and 50 times of atmospheric air. By the large sliding-rod gas this object is effected at once, by taking 42 measures of the one, and 100 of the other.

#### *Piston Valve Volumeter.*

948. I have contrived some instruments for measuring gas with great accuracy, call them volumeters to avoid circumlocution. They are of two kinds, one by introducing it into any vessel containing the gas with which it is to be mixed, over water or mercury; the gas is introduced into the other through an orifice usual in the case of filling a common bottle over the pneumatic cistern. The following figure will convey a correct idea of one of them, which, having a piston valve, I call the piston valve volumeter.

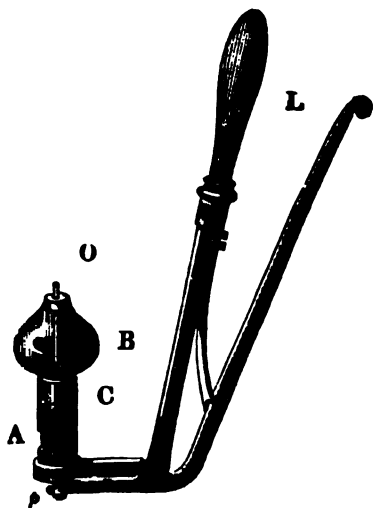
949. The lever, *L*, is attached by a hinge to a piston, *p*, which works in a chamber, *C*. The rod of this piston extends beyond the packing through the bulb, *B*, to the orifice, *O*, in its apex, where it supports a valve, this orifice is kept close, so long as the pressure of the spring, acting on *L*, is not counteracted by the hand of the operator.

950. Suppose that, while the bulb of this instrument, filled with water or mercury is within a bell glass containing a gas, the lever be pressed towards the bulb, the valve consequently is drawn back, so as to open the orifice in the apex of the bulb, and at the same time the piston descends below the aperture, *A*, in the

The liquid in the bulb will now escape, and be replaced by gas, securely included, as soon as the pressure of the spring is allowed to push the piston beyond the lateral aperture in the lever, and the valve into the orifice in the apex of the bulb.

951. The gas, thus included, is transferred to any vessel, inverted over mercury or water, by depressing the piston of the bulb below that of the liquid, and moving the lever, *L*, so as to open the aperture, *A*, in the chamber of the bulb simultaneously.

952. The bulk of gas, included in the volumeter, will always be the same, the quantity will be as the density of the gas into which it may be introduced. Hence, in order to measure accurately, the liquid, whether mercury, over which it may be introduced, should be of the same height without. This is especially in the case of mercury, which, in weight to water as 13.6 to 1, a density of a gas materially; or



its surface within the containing vessel does not deviate sensibly from the level surface without.

*Sliding Rod Gas Measure.*





To remove this source of inaccuracy I employ a small gauge, which communicates through a cock in the neck of the bell, with the gas within. In this gauge gas liquid will answer, which is not absorbent of the gas. In the case of ammonia liquid ammonia may be used; in the case of muriatic acid gas, the liquid. The gauge is simply an inverted glass syphon, of one of the legs of which is made to communicate with that of the receiver, holding the gas, while the other is open to the atmosphere. Even mercury may be used in such an instrument with sufficient accuracy, because the legs of the syphon being near to each other, the minute disparity in the heights of the two adjoining columns of the liquid rising the syphon will be discernible.

#### Simple Valve Volumeter.



954. Besides the lower orifice, O, by which it is filled with gas, the volumeter which this figure represents, has an orifice at its apex, A, closed by a valve attached to a lever. This lever is subjected to a spring, so as to receive the pressure requisite to keep the upper orifice shut, when no effort is made to open it.

955. When this volumeter is plunged below the surface of the water in a pneumatic cistern, the air being allowed to escape, and the valve then to shut itself under the water, on lifting the vessel it comes up full of the liquid, and will remain so, if the lower orifice be ever so little below the surface of the water in the cistern. Thus situated, it may be filled with hydrogen, proceeding by a tube from a self-regulating reservoir. (797, 798.) If the apex, A, be then placed under any vessel, filled with water and inverted in the usual way, the gas will pass into it as soon as the valve is lifted.

956. Volumes of atmospheric air are taken by the same instrument, simply by lowering it into the water of the cistern, placing the apex under the vessel into which it is to be transferred, and lifting the valve: or preferably by filling it with water, and emptying it in some place out of doors, where the atmosphere may be supposed sufficiently pure, and afterwards transferring the air, thus obtained, by opening the valve, while the apex is within the vessel in which its presence is required. In this case, while carrying the volumeter forth and back, the lower orifice must be closed. This object is best effected by a piece of

l, or a pane of glass. It is necessary that the water, the atmosphere, and should be at the same temperature during the process.

#### USUAL COMPOUNDS OF NITROGEN WITH OXYGEN.

These compounds are five in number, *nitrous* and *nitride*, and *hyponitrous*, *nitrous*, and *nitric acid*. Their composition is given in the following table:—

or 1	1 vol.	or 1 atom oxygen,	1 vol. nitrous oxide.
of ni-	1 "	or 2 atoms "	2 vols. nitric oxide.
3 =	1½ "	or 3 "	" hyponitrous acid.
atoms,	2 "	or 4 "	" 1 vol. nitrous acid.
	2½ "	or 5 "	" nitric acid.

#### Of Protoxide of Nitrogen, or Nitrous Oxide.

1. This compound does not exist in nature. When artificially obtained it is gaseous; yet the experiments of

Mr. Faraday have taught us that under great pressure, it may be converted into a liquid.

959. *Preparation.*—Nitrous oxide may be obtained by the action of dilute nitric acid upon zinc, or by exposing nitric oxide gas to iron filings, sulphites, or other substances attractive of oxygen. It is best procured by subjecting nitrate of ammonia to heat, and receiving the product in an apparatus described in the following article. As pure water absorbs this gas, Berzelius receives it over a saturated solution of common salt.

*Apparatus for evolving and collecting Nitrous Oxide.*

960. This apparatus is represented by the opposite engraving. A, is a copper vessel of about eighteen inches in height, and nine inches in diameter, which is represented as being divided longitudinally, in order to show the inside. The pipe, B, proceeds from it obliquely, as nearly from the bottom as possible.

961. Above that part of the cylinder from which the pipe proceeds, there is a diaphragm of copper, perforated like a colander. A bell glass is surmounted by a brass cock, C, supporting a tube and hollow ball, from which proceed on opposite sides two pipes, terminating in gallows screws, D D, for the attachment of perforated brass knobs, soldered to flexible leaden pipes, E E, communicating severally with leathern bags, F F, of suitable dimensions.

962. The beak of the retort must be long enough to enter the cylinder, so that the gas, in passing from the mouth of the beak, may rise under and be caught by the diaphragm. This is made concave on the lower side so as to cause the gas to pass through the perforations already mentioned, which are all comprised within a circle less in diameter than the bell glass. The gas is, by these means, made to enter the bell glass, and is, previously to its entrance, sufficiently in contact with water, to be purified from the acid vapour which usually accompanies it. On account of this vapour, the employment of a small quantity of water, to wash the gas, is absolutely necessary; and for the same reason, it is requisite to have the beak of the retort so long as to convey the gas into the water without touching the metal; otherwise the acid vapour would soon corrode the copper of the pipe, B, so as to enable the gas to escape. But while a small quantity of water is necessary, a large quantity is productive of waste, as it absorbs its own bulk of the gas. On this account I contrived the apparatus here described, in preference to using gasometers or air-holders, which require larger quantities of water.

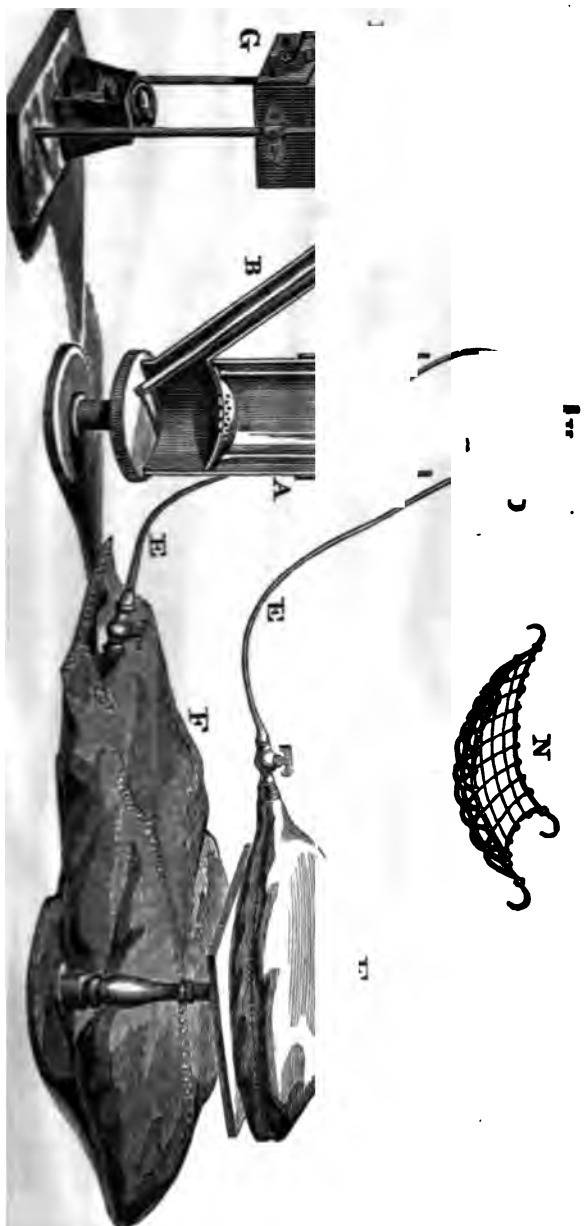
963. The furnace, I, is so contrived, that the coals, being situated in a drawer, G, may be partially or wholly removed in an instant. Hence the operator is enabled, without difficulty, to regulate the duration and degree of the heat. This control over the fire is especially desirable in decomposing the nitrate of ammonia, as the action otherwise might suddenly become so violent as to burst the retort. The iron netting, represented at N, is suspended within the furnace, so as to support the glass retort, for which purpose it is peculiarly adapted. The first portions of gas which pass over, consisting of the air previously in the retort, are allowed to escape through the cock, H. As soon as the nitrous oxide is evolved, it may be detected by allowing a jet from this cock to act upon the flame of a taper.

964. To obtain good nitrous oxide gas, it is not necessary that the nitrate of ammonia should be crystallized; nor does the presence of a minute quantity of muriatic acid interfere with the result. I have employed advantageously, in the production of this gas, the concrete mass formed by saturating strong nitric acid with carbonate of ammonia.

965. The saturation may be effected in a retort, and the decomposition accomplished by exposing the compound thus formed to heat, without further preparation.

966. *Rationale of the Process.*—Nitrate of ammonia consists of nitric acid and ammonia; nitric acid, of five atoms of oxygen and one of nitrogen; and ammonia, of one atom of nitrogen and three atoms of hydrogen.

*Apparatus for cooling and collecting Nitrous Oxide.*









***Combustion of Phosphorus in Nitrous Oxide.***



**(Page 181.)**

one atom of this salt, five atoms of oxygen, three of hydrogen, and two nitrogen are, therefore, present. It must be evident that if, in consequence of the heat, each atom of hydrogen takes one of oxygen, there will be one atom of oxygen left for each atom of nitrogen. Hence, the salt of the salt is resolved into water, and protoxide of nitrogen or nitrous oxide.

**67. Properties of Nitrous Oxide.**—It is a permanent gas. 100 cubic inches weigh 47.25 grains. It supports combustion of a candle flame vividly; though nitric oxide gas, containing twice as much oxygen, extinguishes it. Phosphorus is difficult to inflame in it, but burns with rapidity when once on fire. The habitudes of sulfur are in this respect analogous to those of phosphorus. An iron wire burns in it nearly as well as in oxygen. Most of the combustible bodies burn in nitrous oxide. When ignited with hydrogen, an explosive reaction ensues, and water and nitrogen result. It has no attribute of acidity. When respired it stimulates and then destroys life. Its effects on the human system, when breathed, are analogous to a transient, peculiar, various, and generally very vivacious ebriety. It is much more rapidly and extensively soluble in water than oxygen. Homberg's pyrophorus, or that which I have contrived to obtain from Prussian blue, takes fire on falling through the gas. Agreeable to the researches of Faraday, to the results of which an allusion has been made, when nitrate of ammonia was heated at one end of a sealed recurved tube, nitrous oxide was condensed into a liquid at the other end.

### *Experimental Illustrations.*

**968.** The process and apparatus for producing, collecting, and breathing nitrous oxide gas, exhibited. The effect on a lighted candle and on an iron wire, shown.

### *Combustion of Phosphorus in Nitrous Oxide.*

**969.** There is a singular indisposition in the oxides of nitrogen to part with their oxygen to phosphorus, until it be intensely ignited either by an incandescent iron, or by the access of uncombined oxygen.

**970.** This characteristic in the case of nitrous oxide, may be illustrated by means of an apparatus, like that employed for the combustion of phosphorus in oxygen, and of which the opposite engraving is a representation. It consists of a tall cylindrical receiver, and a tube descending through the liquid and along the axis of the receiver, terminating in a capillary orifice in the cup for holding the phosphorus. The upper end of the tube, out-

cock, to which a gum-elastic  
 receiver having been ex-  
 hausted previously placed within the c  
 as soon as the cock commences  
 intense combustion ceases; s  
 illary orifice of the tube, re-  
 active combustion, which the  
 energy.

*Of Nitric Oxide, formerly called Nitrous Air.*

972. This oxide is an artificial product, and is ob-  
 tained only in the gaseous state. Its tendency to combin-  
 e with oxygen renders it impossible for it to exist where the  
 atmosphere has access.

973. *Preparation.*—Nitric oxide is evolved during  
 the reaction between nitric acid, and copper, silver, and  
 other metals.

*Self-regulating Apparatus for generating Nitric Oxide.*



974. The command of a sufficient quantity  
 of nitric oxide is most conveniently attained  
 by means of a self-regulating apparatus, in  
 the manner which I am about to describe.

975. A vessel, perforated at the top, and in  
 other respects resembling a decanter; having  
 a long neck, surmounted by an inverted  
 U-tube, cap, cock and gallows screw, is placed  
 over a glass jar of suitable dimensions, as  
 represented in the adjoining figure. By means  
 of the gallows screw, a flexible leaden pipe  
 is attached, as to form a communication with  
 the bore of the cock. The cavity of the jar  
 being supplied with copper shreds or turnings,  
 and the jar with diluted nitric acid, by the  
 action of the metal with the acid, gas is  
 copiously evolved, producing red fumes of  
 nitrous acid with the oxygen of the air.  
 The emission of the gas should be regulated  
 until the red fumes disappear. The cock  
 can then be closed, unless it be desirable to  
 transfer the gas to another vessel.

976. It should be understood that the acid passes into and out of the jar  
 through the perforation in the stem; while by means of a fragment of  
 glass, the metallic shreds are prevented from escaping.

977. *Properties.*—Nitric oxide is colourless, perm-  
 ittedly elastic, and rather heavier than air. By water it  
 is slightly absorbed. It is not acid. It extinguishes  
 a candle flame, but ignites Homberg's pyrophorus, and su-

the combustion of phosphorus, if inflamed before immersion in it, or aided by the access of a minute quantity of oxygen. It is fatal to animals, renders the flame of hydrogen green by mixture, does not explode with it, but explodes with ammonia. It unites rapidly with oxygen gas, the oxygen of the air, or of any other gaseous mixture, producing remarkable red acid fumes. It is absorbed by the green sulphate and the protochloride of iron. The solution acquires the property of absorbing oxygen, and is therefore used in eudiometry. Nitric oxide is decomposed by moistened iron filings; also by ignited charcoal, arsenic, zinc, and potassium.

*Experimental Illustrations of the Properties of Nitric Oxide.*

978. Copper or silver being subjected to nitric acid, nitric oxide gas is extricated, and collected in bell glasses over water or mercury.

979. Absorption of nitric oxide gas by protochloride, and protosulphate, of iron, shown: also the method of ascertaining its purity by the sliding-rod eudiometer; and its application to eudiometry, in various ways, by means of that, and other eudiometrical instruments.

980. Self-regulating reservoir of nitric oxide gas for eudiometrical experiments. Absorption of oxygen gas by nitric oxide, and the consequent acidity, made evident by the effect on litmus. Pyrophorus in falling through the gas is ignited.

*Of Hyponitrous Acid.*

981. This acid was isolated in the following manner by Dulong. Having subjected a mixture of four volumes of nitric oxide with one of oxygen, in a tube, to a freezing mixture, he obtained the acid in question in the form of a deep green liquid so volatile as to be converted into a red vapour, unless restrained by intense cold. The hyponitrous acid, thus procured, is partially decomposed by water into nitric oxide which escapes; while the oxygen, combining with another portion of the hyponitrous acid, forms nitric acid. This unites with the water, and protects the remainder of the hyponitrous acid from decomposition. According to Berzelius, it is formed, in combination with bases, when nitrates are kept at a red heat for some time. It is alleged that a hyponitrite of lead is produced, when nitrate of lead is boiled with metallic lead.

982. Hyponitrous acid, when isolated, does not combine directly with bases, but is resolved by contact with them into a nitrate and nitric oxide. Nevertheless it may be transferred from one base to another. It is

alleged to form a crystalline compound with sulphuric acid, and to combine with nitric acid; but it is questionable whether, in combining with nitric acid, it is not resolved into nitric oxide and nitric acid. As an ingredient in one of the ethereal compounds formed by the reaction of nitric acid with alcohol, this acid appears to have some practical importance. Of the ether thus formed it would be premature to treat, until the subject of etherification is undertaken.

### *Of Nitrous Acid.*

983. This combination may be procured in the gaseous state, by mixing two volumes of deutoxide of nitrogen, and one of oxygen; or by subjecting fuming nitric acid to heat, and collecting the product in a receiver. It is also procured by distilling nitrate of lead. Moist nitrous acid is a gas of a deep red colour. When anhydrous, it is a liquid of an orange-yellow which boils at  $72^{\circ}$ . In this form it may be obtained by passing deutoxide of nitrogen and oxygen, *both previously dried*, through a tube filled with fragments of porcelain; or by desiccating the nitrate of lead before employing it as above mentioned.

984. As the compound, consisting of one atom of nitrogen and four atoms of oxygen, called *nitrous acid* by the chemists of Great Britain, decomposed when presented to bases. Berzelius does not regard it as a distinct acid: but gives the name in question, to the trioxide of nitrogen, (756) called *hyponitrous acid* by the British chemists.

985. The tall receiver and the pear-shaped vessel in its vicinity, being filled with water, and placed upon the shelf of the hydro-pneumatic cistern, (609, &c.) as represented in the engraving, by means of cocks with galloways screws, and a leaden pig properly attached, render it practicable to make between them a communication pleasure.

986. These preparations being made, allow the pear-shaped vessel, which I call a volumeter, to be twice filled with nitric oxide, and as often allowed to yield its contents to the receiver. Then fill the volumeter with oxygen gas. In the next place, open the communication again with the receiver. The oxygen, passing into the nitric oxide, produces dense fumes of nitrous acid. At first, in consequence of the rise of temperature which attends the combination, there appears some expansion; but a speedy absorption of the nitrous acid generated, causes the water to rise and nearly fill the receiver. From some hidden cause, I have never been able to attain a complete condensation by this process, however pure might be the gaseous materials employed.

### *Application of Nitric Oxide Gas to Eudiometry.*

987. The property which this substance has of forming with oxygen, nitrous or hyponitrous acid, either of which is absorbed by water, has caused it to be used in eudiometrical operations; but owing to the variable proportions in which the above mentioned compounds are liable to be formed, the results obtained have been deemed uncertain, and the directions for using nitrous oxide, given by such eminent chemists as Dalton, Gay-Lussac, and Thomson, are at variance. Gay-Lussac gave an empirical formula, agreeably to which one-fourth of the condensation produced by a mixture of equal parts of atmospheric air and nitric oxide, is to be assumed as the atmospheric oxygen present.

988. As in two volumes of nitric oxide, a volume of nitrogen is combined with one volume of oxygen, occupying the same bulk as if merely mingled,—to convert the nitric oxide into nitrous acid, which consists of the same quantity of nitrogen with two volumes of oxygen, one volume of oxygen must be added. Of course, nitrous acid be the product, one-third of the deficit produced, would be the quantity of atmospheric oxygen present. This would be too much to correspond with the formula of Gay-Lussac.

989. Supposing hyponitrous acid produced, only half as much oxygen would be required as is necessary to produce nitrous acid; so that instead of the two volumes of nitric oxide taking one volume, they would take only half a volume. The ratio  $\frac{1}{2}$  in  $2\frac{1}{2}$ , is the same as 1 in 5, or one-fifth, which is too little for Gay-Lussac's rule.

990. The formula recommended by Dr. Thomson, agreeably to which one-third

*Synthesis of Nitrous Acid.*



(Page 184.)







*Volumeters for the Analysis of Atmospheric Air by Nitric Oxide.*



eficit is to be ascribed to oxygen, is perfectly consistent with the theory of vo-  
a, and much more consonant with the results of my experiments than that re-  
nended by the celebrated author of that admirable theory.

1. The late Professor Dana ingeniously reconciled Gay-Lussac's statement with  
bary of volumes, by suggesting that half a volume of oxygen may take one  
me of the nitric oxide, and another half volume of oxygen, two volumes.

vol.	vol.
$\frac{1}{2}$ oxygen takes	1 oxide and forms nitrous acid.
$\frac{1}{2}$ oxygen	2 oxide and forms hyponitrous acid.
$\frac{1}{2}$	$\frac{1}{2}$
1	3

The total condensation here would be four volumes, and the deficit due to  
a is one volume, or one-fourth.

With the deference due to a chemist so distinguished as the author of the  
la in question, I long strove unsuccessfully to verify his statements. Agreeably  
reat number of experiments, annually repeated during many years with differ-  
struments, it has been found that, when three volumes of nitric oxide are mix-  
er water, with five of atmospheric air, nearly the same condensation is effected,  
en like quantities of air and hydrogen are ignited together. In order to de-  
rate the truth of this allegation to my numerous class of pupils, I have em-  
i the apparatus represented by the opposite engraving, and described in the  
ag article. In this the volumes employed are so large as to make the results  
gly evident to the most remote observer.

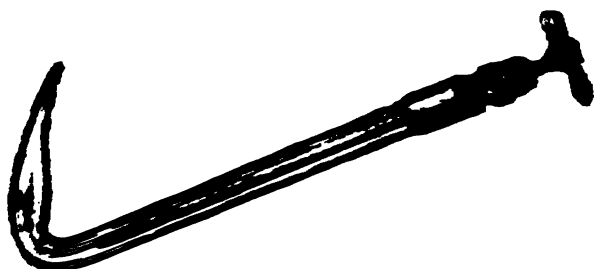
#### *Volumescopie for the Analysis of Atmospheric Air by Nitric Oxide.*

Secured in a screw rod and plate frame, (248,) there is a glass cylinder thirty  
s in height, and about five inches in diameter. Into the brass plate which  
it at top, three cocks are inserted, each provided with a gallows screw. By  
s of a flexible leaden pipe, let one of the cocks be make to communicate with  
pump. Let the other cock, by like means, be made to communicate with a  
shaped glass vessel, which acts as a volumeter, or volume measurer. Let the  
der, by means of scales placed on each side of it, be graduated so as to hold  
volumes, any three of which shall be equivalent, collectively, to the contents  
e volumeter. The apparatus being thus prepared, and secured over one of the  
s of the pneumatic cistern, (611,) exhaust the cylinder by means of the air pump,  
to cause the water to rise in it, until by the scale only five volumes of atmos-  
c air are left, and then open a communication with the volumeter. The air  
used in this vessel will then pass into the cylinder, consequently the water will  
le to the division upon the scale which designates eight volumes, thus showing  
e capacity of the volumeter is equivalent to three volumes as premised. Next,  
as of the pump, raise the water again to the division upon the scale, marking  
clames, and fill the volumeter with nitric oxide. If, under these circumstances,  
ommunication between the pear-shaped vessel and the cylinder be re-established,  
itric oxide will pass into the cylinder, and, combining with the oxygen of the  
used air, will produce nitrous acid in red fumes, which the water will absorb  
y at first. This absorption is promoted and completed by jets of water, pro-  
vertically through the mingled gases, by means of the recurved pipe, and  
lastic bag to which it is attached. It has been shown by the preceding part of  
cess, that the contents of the volumeter, added to five of air, would make  
volumes. were there no absorption; but the actual residue, when the experi-  
is well performed, is always a little less than five volumes, indicating that a  
ore than one volume of oxygen is contained in the five volumes of air em-  
and that this is condensed by combining with twice its bulk of nitric oxide.  
trous acid, usually thus called, consists of one volume of nitrogen and two  
s of oxygen. Of course, to convert into this acid, nitric oxide, consisting of  
same of nitrogen and one volume of oxygen uncondensed, one volume of  
must be added.

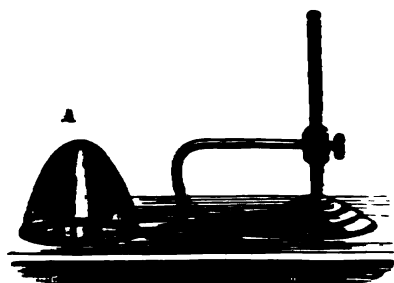
#### *Sliding-rod Eudiometer for the Analysis of Gaseous Mixtures by Absorption.*

The form of the sliding-rod eudiometer represented in the next figure does  
for from that for inflammable mixtures, (140,) as respects the mechanism by  
the rod is secured, or the graduation, which it is convenient to have exactly  
s both. The modification which I am about to consider I found very ser-  
s in the analysis of gaseous mixtures, containing carbonic acid gas, or for

ascertaining the purity of nitric oxide gas by the aid of measurements of air may also be applied to the solution of the impurities of nitric oxide, against the pressure which it exerts within the receiver.



194. The receiver represented in the following cut, shaped like the small one on page 1297, is employed in these experiments, being mounted so as to slide up and down a wire.



195. Being filled with water, and immersed in the pneumatic cistern, the receiver is just even with the surface of the water.—By drawing out the rod of the eudiometer, take into the tube 150 measures of iron-sulphate soln. and transfer the receiver. Next take 50 measures of nitric oxide from a bell as above described, and add it to the air in the receiver. With the mixture of a jet of water, which is easily produced from the apex of the instrument, draw out the whole of residual gas into the tube, continuing to draw out the rod until 150 graduations appear. In the next place eject the residual gas from the instrument: the number of graduations of the rod which remain in the vacuity of the tube, shows the difference produced by the absorption of the oxygen and nitric oxide, in the state of nitric acid.

196. In a great number of experiments, I have found the defect to agree nearly with that produced by the explosion of the same quantity of air with hydrogen, in the aqueous sliding-rod hydro-oxygen eudiometer; but upon the whole rather greater.

*Method of ascertaining the Purity of Nitric Oxide by means of a Solution of Protoxide, or Protosulphate of Iron.*

197. The purity of nitric oxide is easily ascertained by means of a solution of protochloride, or green sulphate of iron, and the sliding-rod eudiometer above described. A small bottle being filled with a solution of the salt, and inverted, the shelf of the hydro-pneumatic cistern, take into the eudiometer one hundred measures of the gas, and transfer them to the bottle, which must be agitated for three minutes. The receiver, being filled with water, and depressed into the shelf of the hydro-pneumatic cistern, till the apex, A, is on a level with the surface, up into it the residual gas. In the next place, draw it into the eudiometer.

198. In doing this it is immaterial how much water may follow, because quantity will be inferred from the number of graduations, which must enter the tube, in order to effect the expulsion. Of course the impurity will be number thus found.

A saturated solution of nitric oxide in the abovementioned ferruginous solution, the power of absorbing oxygen, and was recommended by Sir H. Davy as a method of ascertaining the quantity of that gas in the air. The mode of using it is the same as that just described, taking oxygen into the endiometer of nitric oxide, and filling the bottle with the ferruginous solution of nitric acid of the solution of the pure sulphate or protochloride of iron. I have a method of ascertaining the quantity of oxygen in the air, much more to such less satisfactory than those already described.

### *Theory of Volumes.*

2. It is presumed that a reader, who has carefully this work thus far, may have his attention advantageously directed to the theory of volumes; otherwise guage, now usually employed in treating of combinations resulting from the union of gaseous substances, not always be intelligible to him.

It has been advanced by Gay-Lussac, that sub-  
stances, when aëriform, unite in volumes which are equal,  
when unequal, the larger volume is double, triple,  
quadruple the other.

1. This hypothesis has been verified by experiment as to all substances which are capable, while a, of being combined or decomposed. It is extended to other substances, under the idea that all are capable of the aëriform state. A volume is said to be equivalent of another volume, when capable of combining with it a definite compound, or when just adequate to displace it from combination.

It must be evident, a priori, that if each atom, of  
 er kind, were to occupy in the æriform state an  
 space, atoms might be as well represented by equal  
 s as by their equivalent numbers; the former af-  
 by measure, what the latter give by weight. Now  
 ce justifies the belief that, in general, atoms do  
 an equality of volume when rendered æriform, and  
 then the bulks assumed are unequal, the inequality  
 e removed by multiplying or dividing, by a whole  
 r, those volumes which are smaller or larger than  
 n. This is all that the hypothesis of Gay-Lussac  
 nt.

b. Berzelius infers that water, and the protoxides of phosphorus and nitrogen, each consist of one atom of oxygen, and 8 atoms of the other ingredient. Admitting this to be a direct inference, equivalent weights of the four elementary gaseous substances abovementioned, actually oc-

cupy equal spaces; so that their atoms are as well represented by equal volumes, as by the numbers indicating their ratio to each other in weight. But if we say that, in the compounds abovementioned, there is only one atom of each ingredient, the equivalent volumes of chlorine, hydrogen, and nitrogen, although still equal to each other in bulk, will each be twice as large as the equivalent volume of oxygen. The British chemists, in general, following the last mentioned view of the atomic constitution of the compounds abovementioned, represent the atoms of chlorine, hydrogen, and nitrogen, each by one volume, and of oxygen by half a volume.

1007. When gaseous substances enter into combination, preserving the æriform state, in some cases there is a reduction of volume, in others none. When a reduction does ensue, the bulk, or resulting volume of the compound is to the aggregate bulk of the constituent volumes, as 1 to 2, 1 to 3, 1 to 4, or 2 to 3, 2 to 5, &c.

1008. This will be rendered evident by the following table, in which the number of atoms and the number of volumes which enter into some important compounds are represented by corresponding squares. Each square stands for a volume, and half a square for half a volume. The first column contains the name of each gas or vapour; the second, the equivalent volume of the gas or vapour, or an association of the volumes representing the constituents if compound; the third, the resulting volume of the compound formed; and the last, the pressure expressed in atmospheres, necessary to produce liquefaction.

1009. Among the instances cited in the table, it is seen that there is none in which the bulk of the constituent volumes is to that of the resulting volume in a greater ratio than that of 3 to 1. The only permanent gas, in which the elements are alleged to exist in a state of greater condensation, is olefiant gas, consisting of one volume of the vapour of carbon, and two volumes of hydrogen, condensed into one volume. There are also vapours, consisting of the same elements in the same atomic proportion, in which 8 or 9, or, according to Thomson, even 25 constituent volumes are contained in one resulting volume.

*Table of the Equivalent Weights and Volumes of some Gases and Vapours.*

Gas or Vapour.	Component Volumes.	Resulting Volumes of Compounds.	Pressure of Liquefaction — Atmospheres.
oxygen . . . . .	<div>O 8</div>		4 at 60°
hydrogen . . . . .	<div>Cl 36</div>		
oxide of chlorine . . . . .	<div>Cl 36</div> <div>O 8</div>	<div>44</div>	
ammonia . . . . .	<div>H 1</div>		
hydrogen . . . . .	<div>H 1</div> <div>I 0 8</div>	<div>9</div>	40 at 50°
hydrochloric acid . . . . .	<div>C 36</div> <div>H 1</div>	<div>37</div>	
nitrogen . . . . .	<div>N 14</div>		
atmospheric air . . . . .	<div>N 14</div> <div>N 14</div> <div>O 8</div>	<div>36</div>	
nitrous oxide . . . . .	<div>N 14</div> <div>O 8</div>	<div>22</div>	50 at 45°
nitric oxide . . . . .	<div>N 14</div> <div>O 8</div> <div>O 8</div>	<div>30</div>	
nitrous acid . . . . .	<div>O 8</div> <div>O 8</div> <div>N 14</div> <div>O 8</div> <div>O 8</div>	<div>46</div>	
nitric acid . . . . .	<div>H 1</div> <div>H 1</div>	<div>17</div>	
hydrogen . . . . .	<div>N 14</div> <div>H 1</div>		6½ at 50°

*Of Nitric Acid.*

1010. Although, under ordinary circumstances, nitrogen will not combine with oxygen; yet, when mixed with it, and exposed to a succession of electric sparks, nitric acid, one of the most important agents in chemistry, is generated. Berzelius alleges that traces of nitric acid, in combination with ammonia, may almost always be discovered in the rain water accompanying thunder storms. This chemical combination is probably produced by lightning. The same author states that when a jet, consisting of one volume of nitrogen and fourteen of hydrogen, is inflamed while flowing into a vessel containing oxygen, nitric acid is produced. There are probably some unknown means by which chemical union is induced between nitrogen and oxygen; whence the great quantity of nitrate of potash spontaneously produced in various situations.

1011. It has been supposed that this acid is formed during the eudiometrical analysis of atmospheric air by hydrogen; and that the deficit being thus increased, leads to an undue estimate of the oxygen. I consider this impression erroneous; as upon one occasion, by exploding successive portions of hydrogen with atmospheric air, collected nearly half an ounce of water, and found it devoid of acidity.

1012. *Preparation.*—The production of nitric acid by electricity is too laborious to be resorted to for the purpose of the chemist.

1013. Agreeably to the usual process, nitre, which consists of nitric acid and potash, is subjected to heat with an equal weight of sulphuric acid, in a glass, porcelain, or iron retort, communicating with a glass receiver. The nitric acid is displaced by the superior affinity of the sulphuric acid for the potash, and, being vaporized by the heat, passes into the receiver, where it condenses into a liquid. Thus obtained, it is more or less contaminated with nitrous acid or nitric oxide, also with chlorohydric, and sulphuric acid. By distilling from it about a third of the whole quantity, the nitrous and chlorohydric acids pass over in the receiver with the portion of nitric acid distilled, leaving the residue in the retort free from them. Sulphuric acid may be removed by distilling the nitric acid from one eighth of its weight of pure nitre, or by the addition of



which precipitates in the form of an insoluble compound with the sulphuric acid. Chlorohydric acid may in another manner be removed by a solution of silver; as this forms with the chlorine an insoluble compound which settles.

*Properties.*—Nitric acid emits pungent suffocating and has a peculiar odour. When pure it is colourless when exposed to the light, it is slowly decomposed into oxygen gas, and nitrous acid or nitric oxide is absorbed, giving an orange colour to the nitric acid. This decomposition takes place much more rapidly in the sun. Nitric acid cannot be obtained free from water. With almost all the metals it reacts powerfully, also with organic substances, causing them to be oxidized. It corrodes and destroys the skin. It may be considered as one of the ingredients of atmospheric air in the liquid state containing ten times as much of the active principle as oxygen. It is the most energetic principle in gunpowder. In its highest state of concentration, at a specific gravity of 1.55, one atom of the acid contains one atom of nitrogen. This concentrated acid boils at  $175^{\circ}$  and freezes at  $-10^{\circ}$ . When it contains one atom of acid to four of water it has a specific gravity of 1.42, and boils at  $248^{\circ}$ . Nitric acid, whether weaker or stronger than this, has the same freezing point at a lower temperature. If weaker it is strengthened, if stronger it is weakened, by boiling; and at all degrees of strength become, by the continued application of a sufficient degree of heat, of the specific gravity of 1.42. The officinal specific gravity is 1.5, in which case it contains two atoms of water to one of acid. Nitric acid is employed in giving a yellow colour, and for various other purposes in manufactures. It is used in medicine for fumigations, in cases in which chlorine is contraindicated.

### *Experimental Illustrations.*

1. The extrication and distillation of nitric acid, may be effected by means of a glass retort and receiver, heated by a water or small sand bath. Its action on various substances is exemplified.

*Of the Orange-coloured Fuming Nitric Acid, called Nitro-nitric Acid in the Swedish Pharmacopæia.*

1017. In whatever proportion sulphuric acid may be employed in the process just described for procuring nitric acid, the liquid obtained is of an orange colour. This colour becomes deeper, when the quantity of sulphuric acid employed is insufficient to produce a bisulphate with the potash. I am under the impression that, in some degree the same result follows when the acid exceeds the proportion requisite to produce the bisulphate. In either case the water, which in the absence of some other base is indispensable to the existence of nitric acid, is not furnished in sufficient quantity. Hence the acid is partially resolved into oxygen and nitrous acid, which latter, together with the nitric acid, passes into the receiver, constituting an orange-coloured fuming liquid, mentioned by Berzelius under the name of *nitroso-nitric acid*. This acid, by exposure to heat, disengages nitrous acid gas, and becomes colourless nitric acid. Nitroso-nitric acid ignites essential oils, carbon, and phosphorus; the latter explosively. It is much more energetic in its reaction with such substances than pure nitric acid, which, probably, when nitric oxide is not present, requires for its existence a larger proportion of water. I deem it probable that it is with nitric oxide not nitrous or hyponitrous acid, that nitric acid is combined in nitroso-nitric acid. Berzelius conceives that either view of its composition may be correct.

*Experimental Illustrations.*

1018. Reaction of nitroso-nitric acid with carbon and oil of turpentine, exhibited, also with caoutchouc tar.

*Of the Agency of Nitric Oxide in generating Sulphuric Acid.*

1019. When nitric oxide, atmospheric air, sulphurous acid, and aqueous vapour are mingled, a crystalline compound is formed, which, if the operation be performed within a glass vessel, will appear upon the interior surface in a crystalline deposition, resembling hoar frost. When water is added to this compound, it is resolved into sulphuric acid and nitric oxide. The former combines with the water, while the latter escapes in the gaseous form, producing with oxygen, if present, the red fumes of nitrous, or hyponitrous acid. It may be inferred that hyponitrous acid, produced as above mentioned, yields one atom of oxygen to the sulphurous acid, converting it into sulphuric acid. The acid, thus produced, unites with the nitric oxide

and water: but on being subjected to a larger portion of water, for which it has a greater affinity, the nitric oxide is allowed to escape. These habits of the agents in question excite greater interest, on account of their agency in the generation of sulphuric acid, one of the most valuable of the instruments which have been placed within the reach of the chemist, artist and manufacturer.

*Experimental Illustration of the Reactions which occur in the Manufacture of Sulphuric Acid.*

1020. Into a glass globe with three tubulures, insert through one of them, the neck of a pint retort, containing about a pound of mercury, and as much sulphuric acid as will cover it to the depth of half an inch, applying to the retort a chauffer of coals. Into the other tubulure, fasten the termination of a pipe proceeding from a self-regulating reservoir of nitric oxide gas. The third tubulure should be closed by a glass stopple. The mercury releases one atom of oxygen from the sulphuric acid, converting it into sulphurous acid which enters the globe. As soon as this appears to have taken place, a portion of the nitric oxide gas is allowed to enter from the opposite end. Meeting with atmospheric air within the vessel, the nitric oxide will produce red fumes, which, encountering the sulphurous acid, will condense into a crystalline deposition. Occasionally, the stopple must be lifted to allow the access of fresh air; and the supply of this and the gases must be so regulated, that the red fumes shall be repeatedly produced and condensed. When a deposition of crystalline matter, sufficiently striking, has been produced, if water be poured into the globe, the deposition will be readily decomposed with an evolution of nitric oxide. This gas, meeting with the oxygen of the air, produces red fumes, which, by the readmission of sulphurous acid, are again condensed with it into crystals. These crystals, as before, by the addition of water, are decomposed into nitric oxide and sulphuric acid. The water in the globe, being decanted and tested, gives decided indications of the presence of sulphuric acid.

1021. Lately, the process above described, has been resorted to in a large way in the manufacture of sulphuric acid. In some cases the nitric oxide has been evolved by the reaction of nitric acid with organic substances of a nature to produce oxalic acid, but in other manufactories the nitric oxide is obtained from nitric acid by subjecting it to sulphuric acid, which causes it to be resolved into nitrous or hyponitrous acid fumes and oxygen gas.

1022. When nitric oxide is obtained by the reaction of nitric acid with sugar or molasses, oxalic acid is produced, and tends to defray, partially, the expense of the process.

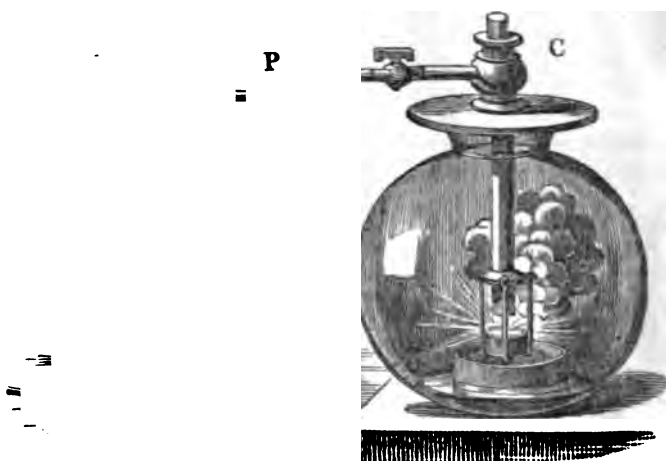
*Of the Process usually employed in the Manufacture of Sulphuric Acid.*

1023. The combustion of one portion of sulphur, and the simultaneous deflagration with nitre of another portion, (the fumes created in both ways being received in a large chamber lined with lead, and covered at bottom with water) are the means usually employed for the manufacture of sulphuric acid. Each atom of nitre contains an atom of potash and an atom of nitric acid. Three out of the five atoms of oxygen in each atom of the acid, unite with an atom of sulphur, converting it into sulphuric acid, which combines with the potash. The two remaining atoms of oxygen, together with the nitrogen of the acid, are evolved as nitric oxide, which, with sulphuric oxygen, moisture, and the sulphurous acid produced by the burning of sulphur, generates the crystalline compound above described. Of late years, the use of an adequate quantity of moisture has been insured by the introduction

of steam at proper intervals. The crystalline compound, subsiding into the water, is decomposed into sulphuric acid, which remains in solution, and nitric oxide gas, meeting with further portions of oxygen and sulphurous acid, again contributes to the formation of the crystalline compound, to be again decomposed. The process is continued until the water in the chamber becomes sufficiently impregnated with sulphuric acid, when it is transferred to leaden boilers. In these it is concentrated by boiling, but it is removed before it attains sufficient strength to attack lead, to a platinum alembic, or to glass retorts, and boiled down to the specific gravity of 1.85. After it has reached that density, no farther concentration can be effected by heat. This, accordingly, is the standard specific gravity of the sulphuric acid of commerce.

*Production of Sulphuric Acid further illustrated.*

1024. The apparatus here described, serves to show, in miniature, the process of generating sulphuric acid.



1025. Provide a globular glass vessel with a wide mouth fitted to a suitable cork and capable of holding at least eight gallons, represented by the preceding figure. Through a hole in the centre of this plate, a gun barrel, open at both extremities, is made to descend. From the lower extremity, a ring of about two inches in diameter is suspended by wires, hooked to a perforated circular piece of sheet metal, which encircles and is soldered to the barrel. In the ring thus suspended, a conical frustum of iron, having an hemispherical cavity, is seated, so as to be a little above the water. Between the outside of the gun barrel, and the inside of the brass cup, C, which supports it, there is a passage from the pipe, P, into the cavity of the globe. This pipe communicates also with the water of a tumbler, supported within the glass. A tube leads from a suction pump into this vessel, which is placed on a shelf of the pneumatic cistern, covered with water as usual.

1026. The apparatus being thus arranged, the metallic plate, with the gun barrel, ring, and frustum appended to it, must be removed from the globe, the iron frustum lifted out of the ring, and some nitrate of potash (nitre) being introduced into the cavity in the frustum, it must be made moderately red-hot. It is then to be returned to its seat in the ring, below the gun barrel, and the plate and gun barrel must be returned to their previous position over the mouth of the globe, so that the nitre may be situated as represented in the engraving. Lumps of brimstone, about the size of peas, are to be dropped through the gun barrel into the melted nitre. As each lump reaches the nitre a combustion ensues, equally remarkable for beauty and brilliancy. The globe then becomes filled with sulphurous acid gas, accompanied by nitric oxide gas, and a crystalline deposition ensues. Meanwhile, to keep a supply of oxygen within the globe, and to prevent the escape of fumes into the apartment, the suction pump is put into operation, in order to draw the fumes out of the globe, and cause them to be replaced by air, which enters through the gun

1027. The water rises from the cistern into the bell, until the resistance which it offers to further elevation, is greater than that which the water, in the tumbler on the stand, opposes to the entrance of air from the pipe; and, consequently, the air is drawn from the globe through the water in the tumbler, by which the fumes arising from the combustion are arrested, especially if liquid ammonia shall have been previously added to the water.

1028. To protect the globe from the heat of the red-hot iron frustum, a cylinder of sheet lead is placed below it, as represented in the figure.

1029. The fumes generated during this process, condense upon the inner surface of the globe, into a white crystalline compound, identical with that procured in the process above described. By the affusion of water, this crystalline matter undergoes a decomposition like that already described, (1020,) giving out nitric oxide, and yielding sulphuric acid to the water.

## COMPOUNDS OF NITROGEN WITH CHLORINE AND IODINE.

1029. Neither chlorine nor iodine combines directly with nitrogen; but both unite with the nitrogen of ammonia, under circumstances which I shall mention presently.

### *Of Chloride of Nitrogen.*

1030. This compound may be obtained by placing a bell glass, filled with chlorine, over a solution of one part of nitrate of ammonia in twelve of water, at the temperature of  $70^{\circ}$ . The chloride appears in drops, which resemble olive oil, and which, being heavier than water, subside to the bottom of the basin containing the solution. It is remarkable that this substance does not explode with many combustibles, which would appear more likely to decompose it than those with which it does explode. Thus it explodes with turpentine or caoutchouc, but not with camphor.

1031. The force with which a minute portion of chloride of nitrogen explodes, on contact with oil of turpentine, would hardly be credited by those who have not witnessed this phenomenon. An open saucer of Canton china was fractured by a globule not larger than a grain of mustard seed. The glass tube employed to project the globule into the saucer, was violently dispersed in fragments.

### *Of Iodide of Nitrogen.*

1032. When iodine is kept in liquid ammonia, it is converted into a brownish-black substance, which is iodide of nitrogen, and which may be collected and dried on bibulous paper at a gentle heat. The iodide of nitrogen thus formed, evaporates spontaneously. It explodes by a slight pressure, or when heated or much dried, being resolved into nitrogen gas and iodine.



## ON SOME POINTS OF CHEMICAL THEORY.

1033. The student has now advanced sufficiently far in practical knowledge of the phenomena of combustion, and of the properties of some acids, to render it expedient to present to him some general views of *combustion*, *acidity*, and *alkalinity*, and additional instruction on *classification* and *nomenclature*. I am the more inclined to this course, as, among the compounds of nitrogen, there are three acids and an alkali.

*Of Theories of Combustion.*

1034. Stahl supposed the existence, in all combustibles, of a *principle of inflammability*, which he called *phlogiston*, from *phlogis* burn. He inferred that all substances, in burning, gave out *phlogiston*. The fallacy of this hypothesis is evident; since metals become heavier on combustion, obviously in consequence of the absorption of oxygen from the atmosphere. By the advocates of the *phlogistic theory*, nitrogen was confounded with carbonic acid, and carbon with hydrogen, because carbon and hydrogen were conceived to consist of *phlogiston* nearly equal to oxygen, in combining with them, was supposed to become *phlogisticated air*, the name then given to nitrogen gas. It is now well known that carbon, oxygen forms carbonic acid, with hydrogen water; as nitrogen gas contains neither carbon nor hydrogen.

1035. Sulphuric, and phosphoric, acid, and metallic oxides, were formerly supposed to be ingredients in the sulphur, phosphorus, and in producing them. Thus of two bodies, that which was actually the *acid* was assumed to contain the other.

1036. The celebrated Lavoisier, to whom we are chiefly indebted for the exposure of these fallacies of the theory of *phlogiston*, having shown that oxygen is an indispensable agent in all ordinary cases of combustion, was erroneously led to infer that it was in all cases necessary to the process. But it is now well known that there are many instances of combustion, in which oxygen has no agency.

1037. I would define combustion to be a state of intense *chemical action*, accompanied by an evolution of heat and light.

1038. That increase or diminution of temperature consequent to *caloric combination*, which constitutes combustion when productive of heat and light, has been ascribed to a mysterious law, by which bodies undergo change in their capacity to hold caloric. It has been supposed that the capacity of the compound is in some instances greater, in others less than the mean capacity of the constituents; and that in the former case it is followed by an absorption of caloric, and of course by cold; in the latter by the expulsion of caloric, and, consequently, the production of heat. Yet, when the capacities of compounds are compared with those of the ingredients, the result does not justify the idea that the heat given out in the latter in combining, is produced by a diminution of capacity. At best this hypothesis only substitutes one enigma for another; since it does not count for the alleged change of capacity.

1039. The diversity of power to hold caloric in a latent state, technically designated by the word *capacity*, is now generally ascribed to the *indirect influence of electricity*. It has been shown\* that, if neighbouring bodies be electrified by means either of glass or resin, previously subjected to friction, they will repel each other; but that if one be thus excited by one and another by resin, attraction between them will ensue. Hence the two excitements are considered of an opposite nature. It will be recollected according to the Franklinian theory, the vitreous excitement results from a redundancy; the resinous, from a deficiency of the electrical fluid. The former being designated as positive, the latter as negative electricity. According to the doctrine of Dufay, the different electric excitements are considered as the effects of two different fluids, attractive of each other, but

\* See my Treatise on Statical Electricity.

pellent. The one has accordingly been called resinous, the other vitreous electricity. Yet, even by electricians, who suppose the existence of two fluids, the terms positive and negative are employed.

1040. It has been suggested that Voltaic phenomena, combustion, acidity, alkalinity, and chemical affinity, may owe their existence to the principle by which the different electric excitements are sustained in electrified bodies, modified in some inexplicable manner, so as to act between atoms instead of masses. This suggestion derives strength from the following facts, which have been fully illustrated in my lectures on electricity and galvanism.

1041. The pole of a Voltaic series, terminated by the more oxidizable metal, has been shown to display a feeble electrical excitement, of the same kind as that which is producible by friction in glass; while the other pole displays the opposite excitement, in like manner producible in resin. From reiterated experimental observation it is now generally inferred, that, of any two elementary atoms, chemically combined, and simultaneously exposed, to the voltaic current, one will go to the positive, the other to the negative pole. Atoms are supposed to have electrical states the opposite of those of the poles at which they may be liberated, and are said to be electro-negative when liberated at the positive pole, or anode; electro-positive when liberated at the negative pole, or cathode. See my Treatise on Galvanism, page 7.

1042. Substances which have opposite relations to the Voltaic poles, have an affinity for each other, which is usually stronger in proportion as the diversity of their electric habitudes is the more marked. Thus, for instance, oxygen, which is pre-eminently electro-negative, and potassium which is pre-eminently electro-positive, have, under ordinary circumstances, a predominant affinity for each other.

1043. On all sides it must be admitted that between chemical reaction, galvanism, and electro-magnetism, there is an intimate association which must be explained before the phenomena of chemical reaction can be well understood.\*

1044. It has been mentioned that, of known bodies, oxygen appears to be the most electro-negative. It is questionable whether the grade next to oxygen, in the electro-negative scale, is to be assigned to chlorine or fluorine. After these follow bromine, iodine, sulphur, selenium, and tellurium.

1045. Among the metals we have a series of substances, varying from those in which the electro-positive power is pre-eminently great, as in potassium, sodium, lithium, barium, calcium, magnesium, &c., to such metals as belong rather to the electro-negative class. Hence, setting out from the extreme above-mentioned, we may proceed through a long range of metals less and less electro-positive, till we arrive at such as produce electro-negative combinations with oxygen or chlorine, or both. More or less within this predicament, I think we find tin, mercury, gold, platinum, palladium, antimony, arsenic, molybdenum, and lastly tellurium. Thus at an intermediate point between the extremes at which oxygen and the alkalis are placed, there are substances whose relation to the Voltaic poles is equivocal or wavering; and it should be understood that this relation is always comparative. Chlorine is electro-positive with oxygen and perhaps fluorine, and electro-negative with every other body. Iodine is electro-positive with oxygen, chlorine, bromine, and probably fluorine, while with other substances it is electro-negative.

\* See my "Treatise on Galvanism, or Voltaic Electricity, for Effects of Galvanic or Voltaic Circuits," page 19. And for Theory of the same, page 35.

1046. Substances of the two opposite classes, in combining with other, constitute compounds which are either electro-positive or electro-negative, accordingly as the different energies of their ingredients predominate. Thus in alkalis, consisting of oxygen united with the alkali metals, the electro-positive influence predominates; while the reverse is of acids, consisting of the same electro-negative principle, oxygen, in combination with sulphur, nitrogen, phosphorus, carbon, boron, silicon, niium, or other substances, which, in their electrical habitudes, lie between oxygen and those metals.

1047. In some cases we see an electro-negative or electro-positive principle attached to compounds, which is not equally displayed by either of the constituent elements separately. Cyanogen, consisting of carbon and nitrogen, is a striking instance of an electro-negative compound thus constituted; and in ammonia, and the vegetable alkalis lately discovered, have instances of electro-positive compounds, produced from principles comparatively electro-negative.

1048. For any further view of the connexion between chemical galvanic reaction, I refer to my Treatise on Galvanism, or Voltaic Electricity, especially to pages 7, 17, 35.

*Of the Influence on Classification and Nomenclature of the Habitudes of Chemical Agents with the Voltaic Series.*

1049. It would follow from the statements made under the last, that there should be a resemblance between the properties of substances which have a proximity to each other in the electric series. (1042.) Accordingly we find, that those which occupy the higher part of the electro-negative scale, have, by distinguished writers, especially in Great Britain, been classed as *supporters*; while those which are electro-positive, or electro-negative, have been by the same authors classed as *combustibles*. Also, certain electro-negative compounds, formed of the pre-eminent electro-negative principles, have been associated as *acids*; while other compounds, of oxygen at least, which have the opposite polarity, have been associated as *bases*, under some of the subordinate divisions of alkaline earths, earths proper, or simply oxides.

1050. The idea of a class of supporters of combustion, and of combustibles, has no better foundation than that certain substances are the most frequent agents in combustion. Thus hydrogen will produce fire with oxygen, chlorine only; sulphur with oxygen, chlorine, and the metals; and carbon with oxygen; but as either oxygen or chlorine will burn with a great variety of substances, they have been called supporters of combustion. The substances with which they combine during combustion, combustibles. Iodine and latterly bromine have been classed among the supporters, because they combine with almost all the bodies with which the other elements classed under that name unite, and in some cases with an evolution of heat and light. Yet they are not gaseous like oxygen and chlorine, are as analogous to sulphur as to oxygen. There appears to me to be an error in taking either of these substances into the class of supporters, sulphur is excluded, which, next to oxygen and chlorine, has the property of burning with the greatest number of substances. In other respects sulphur seems, in its properties, to be intermediate between iodine and phosphorus. The habitudes of selenium appear to range between those of tellurium and sulphur.

1051. Hydrogen, phosphorus, carbon, boron, and silicon are no more



be called combustibles, as, than oxygen, chlorine, bromine, and iodine, are called supporters. It should be observed, also, that these appellations are evidently commutable according to circumstances; since a jet of fired in hydrogen, is productive of a flame, similar to the inflamed jet of oxygen in oxygen. If we breathed in an atmosphere of hydrogen, it could be considered as inflammable, and of course a combustible. The arrangement which I have adopted of classifying as basacigen bodies, which have heretofore been treated as supporters, with the addition of acids, renders it unnecessary to resort to the incorrect division into acids and combustibles.

### 3 of distinguishing Degrees of Oxidisement, derived from the School of Lavoisier.

The method which, in concurrence with Thenard, I have pursued in the case of the compounds formed by the basacigen with radicals, the proportion of the former ingredient has been (756.)

In the case of oxacids another method was adopted by the Lavoisier school, which, with some modification, still endures, and which I use as it now prevails.

Agreeably to the nomenclature in question, where, in consequence of different degrees of oxidisement, substances form two acids, one containing a larger, the other a lesser proportion of oxygen, the acid, having the larger proportion, is distinguished by the name of the substance oxy-ous, and a termination in *ous*; that containing the larger proportion of oxygen is designated in the same way, substituting *ic* for *ous*; as sulphurous and sulphuric acid. That ingredient in an acid or a base, which is electro-negative, is called the radical. When an acid is discovered containing less oxygen than one with the same radical, of which the name ends in *ous*, the word *hypo* is prefixed. Hence the appellations, *hyposulphurous*. The same mean of distinction is employed to designate a degree of oxygenation exceeding that designated by *ous*, but not that designated by *ic*. Hence the name *hypersulphuric*. If there is an acid having still more oxygen than the one of which the name ends in *ic*, the letters *oxy* are prefixed.

Acids of which the names terminate in *ous*, have their salts designated by a termination in *ite*. Acids of which the names end in *ic*, their salts distinguished by a termination in *ate*. Thus we have nitrites and nitrates, sulphites and sulphates. If the base be in excess, the prefix *sub* is prefixed, as *subsulphate*. If the acid be in excess, *super* is prefixed, as *supersulphate*. The letters *bi* are placed before the name of the salt, signifying a double proportion of acid; hence carbonate and bicarbonate. The oxide in which the oxidisement is supposed to be at the intermediate state is called the *peroxide*. This monosyllable, *per*, is also used in the case of acids, to signify the highest state of oxygenation, and has been substituted for *oxy* in the case of *perchloric acid*. Many chemists apply the monosyllable in question to distinguish a salt formed with a peroxide; thus the red sulphate of iron has been called the *persulphate* of iron. In the case of the red oxide of mercury, the *pernitrate* of mercury. Agreeably to a similar rule, salts formed with protoxides have the word *proto* prefixed, as in the instances of *protonitrate*, *protosulphate*, &c.

It has already been stated that by the British chemists the binary compounds of oxygen with chlorine, bromine, iodine, fluorine, and cyanogen, when they are designated by the termination in *ide*.

1058. The word oxide has been erroneously used as a correlative of the word acid, instead of being used as a generic name for any compound of oxygen, whether an acid or base. I should deem it preferable to apply the termination in *ide*, to all compounds of the basacigen bodies, whether acids, bases or neutral, employing the words acid and base as terminations to indicate the subordinate electro-negative, and electro-positive compounds. In that case *oxybase*, *chloribase*, *fluobase*, *bromibase*, *iodobase*, *cyanobase*, *sulphobase*, *selenibase*, *telluribase*, would stand in opposition to *oxacid*, *chloracid*, *bromacid*, *iodacid*, *cyanacid*, *sulphacid*, *selenacid*, *telluracid* (862, &c.) Yet for convenience, the generic termination *ide* might be used without any misunderstanding; and so far the prevailing practice might remain unchanged. Resort to either appellation would not, agreeably to custom, be necessary in speaking of salts or other compounds analogous to them; since it is deemed sufficient to mention the radical, as if the salt consisted of an acid combined with a radical, not an oxide. Ordinarily we say sulphate of lead, not sulphate of the oxide of lead. This last mentioned expression is resorted to, only where great precision is desirable. In such cases, it might be better to say sulphate of the oxybase of lead.

1059. The method of indicating the proportion of oxygen in an oxide by changing the termination from *ous* to *ic*, has been generally adopted only in the case of the protoxide, and bioxide of nitrogen, the former being usually called nitrous oxide, the latter nitric oxide. In the Berzelian nomenclature, this method of discrimination has been extended to all the compounds formed with amphigen and halogen elements. Hence we have chlorure mercurieux, and chlorure mercurique, for the protochloride, and bichloride of mercury; and again, oxide mercurieux and oxide mercurique for the protoxide and bioxide of the same metal. These Berzelian names translated into English would make mercurious chloride and mercuric chloride, mercurious oxide and mercuric oxide.

1060. It should be understood that the employment of the terminations in *eux* and *ique*, which in French answer for *ic* and *ous* in English, is extended, by Berzelius, to the case of all oxides whether acids or bases. These words are, in my opinion, neither agreeable to the ear, nor sufficiently definite and descriptive. In the received nomenclature, besides the case above cited of the bioxide of nitrogen, the only other instance, of the employment of the letters *ic* to designate an oxide, is that of the protoxide of carbon, called carbonic oxide.

#### *Of the Origin of the erroneous Idea of a Ponderable Acidifying Principle.*

1061. At the period when the French nomenclature was adopted, oxygen was considered as the sole *acidifying principle*, whence its name as already stated. (637.) Of course, every acid being supposed to consist of oxygen in part, it was enough to call it an acid to convey a correct idea of its composition in that respect. But when, at a subsequent period, it was shown that many acids were destitute of oxygen, and that other substances were nearly as efficient as oxygen in generating acids by a union with acidifiable bodies, it became necessary to prefix syllables in order to distinguish the acid compounds produced by one acidifying principle, from those produced by others. (856, &c.) The term acidifying principle originated with the error of assigning that character exclusively to oxygen. From convenience, more than any conviction of its propriety, it was afterwards used to

Finally is referred to chlorine, hydrogen, and other elements which are found to produce acids by combining with a variety of substances. It is not so obvious that there is no adequate reason for considering any of these elements as an acidifying principle.

1862. Subsequently to the creation of the word oxygen, the word radiac was employed to designate an acid-forming substance. It has since been applied by me to all substances which form acids or bases with the hydrogen bodies.

### *Of Acidity.*

1863. Acidity and sourness were originally synonymous. By some of the older chemists, the solvent power of certain acid or sour liquids, was ascribed to the sharpness of their constituent particles. To this acuteness in form, the power of penetrating and severing the combinations of other particles was attributed. With people in general, the words acid, and acidity, still retain their original signification; but by modern chemists, substances are associated as acids which are destitute of sourness, and which are extremely discordant in their obvious properties. Thus we have in the group of acids, sulphuric acid and flint, sugar and the tanning principle; also the volatile and ferrous liquid called prussic acid, and the unctuous, insoluble, inert, concrete material for candles, called margaric acid. It might naturally excite the curiosity of the reader, to know by what common characteristic substances so discordant had been affiliated. It would be inferred that there should be some test of acidity, by which to determine whether a new compound should belong to the class of acids or not. I am utterly ignorant of any other common characteristic, in these otherwise heterogeneous substances, besides that common preference for the poles, or "*electrodes*," of the Voltaic series, on which I have founded my definition of acidity and basicity; coupled with the inference, mentioned in a note, that any compound capable of neutralizing a base, is deemed to be an acid; and vice versa, any compound capable of neutralizing an acid, is deemed to be a base.

31.) To me it is quite evident that it is only upon one of the other of these characteristics, that many organic compounds which are called acids, or bases, can have any claim to be designated as they are.

1864. Among the characteristics of acidity heretofore mentioned, is that of reddening vegetable blues. By the

soluble acids, this property is generally possessed, although an aqueous solution of sulphurous acid is said to whiten litmus, the vegetable blue is generally employed as a test of acidity. But indigo is not reddened by any acid although by nitric acid it is destroyed. Solubility, though usually a property of acids, is in many cases wanting, as in those of margaric and stearic acid, and others of similar origin. The acid properties of silicic, and boric, acids are displayed at temperatures incompatible with any other solubility, than that which is effected by the agency of caloric.

### *Of Alkalinity.*

1065. Among the metallic oxides which, agreeably to the definitions above given, are considered as bases, there are a certain number which are called alkalies, on account of some peculiarities which I shall proceed to mention.

1066. All the alkalies have a peculiar taste, called alkaline. They all produce, in certain vegetable colours, characteristic changes, which differ according to the matter subjected to them, but are not varied by changing the alkali.

1067. They restore colours changed by acids, and are capable of neutralizing acidity.

1068. Acids neutralize alkalies, and restore colours destroyed by them. Acids do not usually combine with acids, nor alkalies with alkalies, but acids and alkalies unite energetically with each other.

1069. By the reaction of alkalies with oils, soaps are generated, which are soluble in water.

1070. Besides the alkalies above named, there are four other metallic oxides, those of magnesium, barium and strontium for instance, which have been called earths, and which, in different degrees of intensity, have all the alkaline properties abovementioned, excepting that, if not insoluble, they have an inferior solubility, and that they do not form soluble soaps.

1071. There are also some vegetable compounds which possess, to a sufficient extent, the attributes of alkalies, to be classed among them.

1072. According to Bonsdorf, the halogen elements of Berzelius produce bases, which in some cases display alkalinity. He has noticed a change of colour, indicating an alkaline reaction, on litmus paper, reddened previously by

in acid, and dipped into a solution of a chloride, either of calcium, magnesium, or zinc.

1073. I infer that acidity, basidity, alkalinity, and galvanic polarity, are due to some inscrutable influence of the imponderable cause, or causes, of heat, light, and electricity. To a like influence I ascribe the sweetness of sugar, the pungency of mustard or pepper, and of essential oils, as well as the endless variety of odour with which these last mentioned products are endowed. It is evident that in the organic alkalies and acids, alkalinity and acidity are found to be associated with combinations of ponderable elementary atoms, which exist in other combinations without inducing alkalinity or acidity.

1074. It is my intention, as introductory to the subject of ammonia, to adduce a few experiments which illustrate the properties of alkalies in general.

*Experimental Illustrations of the characteristic Effects of the Alkalies on certain Vegetable Colours.*

1075. Into infusions of turmeric, alkanet, Brazil wood, and rhubarb, a few drops of solutions of either of the alkalies being introduced,—turmeric, from a bright yellow, becomes brown; rhubarb, from nearly the same yellow, becomes red. Brazil wood, from a light red, becomes violet-red; and alkanet, from red, becomes blue. Acids being added, the colours are restored, but by a sufficient quantity of alkali are changed, as in the first instance, and by acids again restored; so that the experiment may be repeated several times with the same infusions.

1076. A blue infusion, obtained from red cabbage, is rendered green by an alkali. By adding some acid, the blue colour is restored; by a further addition of the acid, the infusion becomes red. An alkali being next introduced, it becomes blue, and by a further addition of alkali, the green colour reappears. By alternately using acids and alkalies, these changes may be repeated several times.

1077. The power of various acids in reddening infusions of litmus, shown; and, subsequently, the restoration of the blue colour by an alkali.

## COMPOUNDS OF NITROGEN WITH HYDROGEN.

*Of Ammonia.*

1078. As substances which are analogous in their most important properties, are often utterly different in their composition, it is impossible to adopt any arrangement for treating of them, which may be in both respects satisfactory. The compound which is the subject of this article was naturally associated with the other alkalies, whose composition was unknown; although now generally ranged with the compounds of nitrogen, whilst its former associates are placed among the metallic oxides.

1079. This classification has become the more proper as agreeably to the view latterly presented by Berzelius it appears to be doubtful, whether ammonia be an alkali. But of this I shall speak more fully, in treating of ammonium. (1106, &c.)

1080. Formerly, besides ammonia, only two other alkaline substances were known, soda and potash, or potassium. These being difficult to vaporize, obtained the name of fixed alkalies, while ammonia being naturally æriform, was called the volatile alkali.

1081. A new mineral fixed alkali was discovered in 1817, and named lithia. It was procured from a stone called Petalite. Hence its name from the Greek *λίθος*, stony.

1082. *Preparation of Ammonia.*—Ammonia is obtained from sal-ammoniac, the salt from which it received its name.

1083. To evolve this alkali in the gaseous state, equal parts of sal-ammoniac and quicklime, both finely pulverized, are to be heated gradually in a glass matrass. The ammonia is partially extricated by the mere mixture of the materials; but heat is necessary to complete the operation.

1084. Sal ammoniac, according to the opinion generally entertained, is a compound of chlorohydric or muriatic acid and ammonia. The lime having a greater affinity for the acid than the ammonia, by simple affinity combines with it, and liberates the alkali as a gas, the state which it naturally assumes when isolated. A different view of this subject is taken by Berzelius, which will be explained when treating of ammonium. (1109, 1110.)

85. When it is an object to have the gas perfectly from humidity, it is necessary to arrest the process as as moisture begins to condense in the neck of the receiver; or to interpose, between the neck, and the receiver used to receive the gas over mercury, a tube containing dry hydrate of potash in small fragments.

*Experimental Illustration of the Process for obtaining Gaseous Ammonia.*

86. A flask, containing equal parts of quicklime and ammoniac, both well pulverized and thoroughly interled, is exposed to as much heat as the glass will bear.

87. A bell glass is so placed over the mercurial cistern as to receive any gas which may pass from the orifice of a tube, luted at one end into the flask charged with materials, and at the other entering the mercury so as to be under the bell. This apparatus is represented in the following cut.



88. *Properties of Ammonia.*—Ammonia acts like an alkali upon the organs of taste, upon vegetable colours, and in neutralizing acidity. A very small proportion of gas, diffused in the air, is intolerable to the eyes and to the organs of respiration; yet when extremely dilute, the gas is agreeably stimulating. Its specific gravity is 0.59, and 100 cubic inches weigh 18.28 grains. It is inflammable in the air, yet inflames with chlorine spontaneously, and with oxygen, by the aid of an electric

spark, or galvanic ignition. A candle flame is at first enlarged and afterwards extinguished by immersion in the gas. Water absorbs it with surprising velocity, and will hold from 450 to 670 times its bulk. Ice melts in it more speedily than in a fire.

1089. Heat either decomposes, or volatilizes, all ammoniacal compounds; and either of the fixed alkalies, or one of the three more powerful alkaline earths, disengage ammonia from any of the acids with which it may be combined.

1090. Ammonia, by refrigeration alone, may be condensed into a liquid at  $-40^{\circ}$  F. By a pressure of six atmospheres and a half, Mr. Faraday succeeded in liquefying it at the temperature of  $50^{\circ}$  F.

1091. The decomposition and analysis of ammonia have been attempted by ignition with oxygen gas. I have often caused a mixture of it with oxygen, to inflame by means of a wire ignited by galvanism. I believe it to be almost impracticable to ascertain the result accurately by measurement, on account of the liability of ammonia to be absorbed by the moisture of the apparatus, the water produced by the combustion, and the mercury employed to confine the gases.

1092. A spontaneous and explosive combustion ensues between chlorine and the hydrogen of gaseous ammonia. When chlorine is passed in bubbles through concentrated liquid ammonia, a reaction takes place with so much noise, as apparently to endanger the containing vessel. This process has already been mentioned as one of the means of obtaining nitrogen.

1093. In its reaction with ammonia iodine differs from chlorine. When iodine is brought in contact with dry ammoniacal gas, it forms a thick black fluid, which, when saturated with ammonia, becomes more liquid. This compound is decomposed by water forming the iodide of nitrogen. (1032.)

1094. With various metallic oxides, ammonia forms explosive compounds; especially those known as fulminating gold, and the most dangerous species of fulminating silver. By these appellations, however, other compounds of those metals are designated. By some inexplicable influence, probably electro-chemical, the affinities between the oxygen and hydrogen are suspended without being destroyed. Yet by slight causes, whether mechanical or chemical, the equilibrium is subverted with explosive violence.

### *Experimental Illustrations.*

1095. Sal-ammoniac and quicklime, being powdered, ammonia mixed in small glasses, pungent fumes are emitted. Ammonia extricated by the process above described, and collected in bell glasses over mercury. The introduction of a few drops of water causes the gas to disappear. Ice, in the same way introduced is liquefied, and causes a like result. Characteristic changes effected in the colour of wa



er, tinctured by turmeric, alkanet, Brazil wood, and rhubarb.

1096. Evolution of gas shown by means of potash and an ammoniacal salt, introduced into a glass vessel over mercury.

1097. Equal volumes of ammonia and chlorohydric acid, mixed, and condensed into a solid, constituting sal-ammoniac.

1098. Ammonia inflamed with oxygen gas: also with chlorine.

1099. Synthesis of ammonia by nitric oxide and hydrogen, heated with platina sponge.

#### *Of the Composition of Ammonia.*

1100. According to Berzelius, ammonia was first ascertained to be a compound of nitrogen and hydrogen, by his celebrated countryman, Scheele. At a later period, Berthollet ascertained the ratio in which these substances exist in it, which is by volume that of three of hydrogen to one of nitrogen, condensed into two volumes: and by weight, 3 of hydrogen to 14 of nitrogen. See Table, page 189.

1101. The partial decomposition of ammonia may be effected by subjecting it to a succession of electrical sparks. Each spark causes the decomposition of a portion of the gas; but as the process proceeds, it becomes more difficult, so that a complete decomposition is impracticable. That portion which is decomposed, is doubled in volume; since the three volumes of hydrogen and one of nitrogen occupy, while combined, but half of the space which they would fill if uncombined.

1102. Ammonia, by being made to pass through tubes at a red heat, is resolved into its constituents. This result is promoted by the presence of metallic wire. Any metal will have more or less effect, but iron is most efficacious. It appears from recent experiments of Despretz, that this metal, by continued exposure, may be made to take up nearly twelve per cent. of its weight, becoming a nituret by the absorption of the nitrogen of the ammonia. It is supposed that other metals, which, after a like exposure, exhibit no increase of weight, successively receive and abandon nitrogen; an operation which appears to be singular and mysterious. The metals become brittle during this process. Probably their influence is in its nature electrochemical. In its effects it appears to be the reverse of that by which the union of the elements of water is promoted by the presence of some metals in a state of minute division.

#### *Process for obtaining Water from Ammonia.*

1103. If instead of being conveyed into a bell glass over mercury, the gas be received in water contained in a phial, the water may be saturated, constituting aqua ammoniæ, or water of ammonia. The saturation may be effected in an apparatus, similar to that represented in the following cut.



1104. The absorption of ammoniacal gas by water, causes so much heat, that it is difficult to produce a saturated solution, without assisting the refrigeration by means of ice.

1105. Water saturated with ammonia, when gradually cooled to the temperature of  $-40^{\circ}$  F., crystallizes in long needles having a silky gloss. No doubt these crystals owe their existence to the presence of water, which exists in them as water of crystallization. Water of ammonia is lighter than water. In combining with the gas, the water loses weight in proportion to the degree of impregnation. At the maximum, at ordinary temperatures, the alkali constitutes about one-third of its weight.

#### *Of Ammonium.*

1106. It is well known that Davy resolved potash and soda severally into metals and oxygen, by exposing those alkalis to the divellent influence of the Voltaic current. Subsequently, Berzelius, not having at command an apparatus sufficiently powerful, when unassisted, to effect this decomposition, ascertained that, by placing mercury in contact with a moistened fixed alkali, and in communication with the negative pole, while the alkali communicated with the positive pole, an amalgam would result either of potassium or sodium, according to the alkali employed.

1107. The results, when ammonia is subjected to the galvanic circuit in contact with mercury at the negative pole, having a perfect analogy, as respects the production of an amalgam, with those obtained by a similar exposure of the other alkalis, as abovementioned, led naturally to the

inference that the causes were analogous; and that, in the case in question, no less than in the others, a metallic radical had been deoxidized and united with the mercury. This inference was rendered more plausible by the evolution of oxygen at the positive pole during the formation of the amalgam. Yet ammonia was known to consist of hydrogen and nitrogen; and to consider either or both of these as oxides, was inconsistent with all the knowledge otherwise obtained respecting them. By some chemists, however, nitrogen was conjectured to be the oxide of a metal, with which this amalgam was supposed to be formed. For this supposed metal, the name of *nitricum* was suggested. Hence the contact of the amalgam with water was conceived to cause the absorption of oxygen by the nitricum, and consequently the extrication of hydrogen.

1108. Gay-Lussac and Thenard explained the formation of the amalgam, by supposing the absorption of ammonia by the mercury, together with a portion of hydrogen derived from the simultaneous decomposition of water.

1109. Berzelius admits the fact of the union of the elements of ammonia and hydrogen with the mercury, in the proportions alleged by the distinguished philosophers above named; but conceives that, by the addition of an atom of hydrogen to the ammonia, this alkali is converted into a metal, which he calls *ammonium*. To the union of this metal with mercury, he ascribes the production of the amalgam; and to a resolution of the metal into its elements, the evolution of the ammonia and hydrogen. When an atom of ammonia is presented to an atom of water, he infers that the hydrogen of the water converts it into ammonium, which is simultaneously oxidized by the oxygen. Hence an atom of ammonia, when combined with an atom of water, may be considered as acting as an oxybase of ammonium. When gaseous ammonia is presented to chlorine, one portion of it is decomposed, of which the nitrogen is liberated, while the hydrogen converts another portion into ammonium. This forms with the chlorine a *chloride of ammonium*, and, accordingly, by this appellation, sal ammoniac, or muriate of ammonia, must be designated, agreeably to the hypothesis under consideration.

1110. When in the process already given for obtaining ammonia, chloride of ammonium (sal ammoniac) is mingled with the oxide of calcium (lime) by double elective attraction, the chlorine combines with the calcium, and the oxygen with one atom of the hydrogen in the ammonium; so that water and ammonia are evolved. The latter assumes the gaseous form, while the water unites with the chloride, and remains in union with it, if the heat be not raised unnecessarily, and continued too long.

1111. If we attempt to decompose ammonia without the assistance of mercury, it yields nothing but hydrogen and nitrogen; yet, to produce the amalgam, it is sufficient that the wire employed be coated with mercury. The globule of mercury which is left after the spontaneous decomposition which the mass sustains, is in volume surprisingly minute comparatively with the amalgam which it contributed to form.

1112. The most convenient mode of obtaining the ammoniacal amalgam, is to place a globule of the amalgam of potassium in a cavity of a piece of chloride of ammonium, slightly moistened. The globule soon enlarges to many times its previous dimensions, by the absorption of the ammonium, which relinquishes its chlorine to the potassium.

1113. The ammoniacal amalgam, agitated in dry atmospheric air, yields hydrogen and ammoniacal gas. The same gaseous substances are extricated from it when plunged into ether or naphtha. The ammoniacal

amalgam may be preserved for some time, if surrounded by hydrogen, or included in a dry and well closed bottle. When thus protected, and the absence of water is insured by the presence of a small proportion of potassium, it may be kept unchanged for several months.

1114. Berzelius does not consider ammonia as capable of becoming a base, without first being converted into ammonium by the acquisition of hydrogen. In this state, without further change, it can, like other metals, form a salt by combining with any of the halogen substances. But to combine with oxacids, the ammonium must, like other metals, be oxidized. The presence of water at once metallizes and oxidizes ammonia. The hydrogen converts the ammonia into a metal, while the oxygen converts that metal into an oxide.

1115. When gaseous ammonia precipitates, from an aqueous solution of a haloid salt,\* a metal in the state of oxide, water is decomposed, the hydrogen converting the ammonia into the metal ammonium, while the oxygen converts the metal into an oxide. Meanwhile, the ammonium, combining with the halogen element of the haloid salt, takes the place previously occupied by the metal which has been oxidized.

1116. Agreeably to the view taken above, water, by its contact with ammonia, at once metallizes and oxydizes it, since the hydrogen converts it into ammonium, while the oxygen, at the same time, converts it into an oxide. Thus the formula of ammonia united to water, would be  $NH^3 \times H^2$ ; but when it is resolved into  $NH^4 \times O$ , an oxide of ammonium.

1117. It must also follow, that it is not by ammonia that the part of an alkali is performed when entering the arena of alkaline reaction; with the aid of water a transformation takes place, so that the oxide of ammonium is really the ammoniacal alkali. Of course ammonia cannot, consistently with this explanation, be considered as an alkaline gas.

1118. I deem it expedient to adopt the Berzelian doctrine, as it is necessary to the symmetry of our classification both as respects acids, bases, and chlorides. To consider ammonia, per se, as forming salts with oxacids, or with the halogen bodies, would involve an anomalous deformity, as in all other cases of the union of inorganic acids and bases, the same basacigen ingredient exists both in the acid and the base.

### *Experimental Illustrations.*

1119. In a cavity, made in a bit of muriate of ammonia, in communication with one of the poles of the Voltaic pile, a moistened globule of mercury is supported. The mercury is made to communicate with the other pole. The metal swells rapidly, and assumes all the characteristics of an amalgam.

1120. An amalgam of potassium, being introduced into a cavity in a piece of sal ammoniac, is rapidly converted into the ammoniacal amalgam, with a prodigious enlargement in bulk.

\* A salt formed by a halogen element. (636.)

## SECTION III.

## OF PHOSPHORUS.

1121. *Preparation.*—Phosphorus is obtained from the phosphate of soda in urine, or the phosphate of lime in bones. Impure phosphoric acid may be extricated from the earth of bones, by the stronger affinity of sulphuric acid. As, at a high temperature, charcoal takes oxygen from phosphorus, the phosphoric acid is decomposed by ignition with it in a retort, the beak of which is so introduced into water, as to have the orifice a little below the surface. Phosphorus distils into the water, and condenses in tears.

1122. Agreeably to another process, the phosphate of soda, which may be procured at the shops, is decomposed by nitrate of lead, by complex affinity. The phosphorus is separated from the resulting phosphate of lead, by distillation with charcoal, as in the process above mentioned.

1123. *Properties.*—Phosphorus is often of a light flesh colour, but when pure is colourless and translucent. It is rather harder than wax, but is more easily divided by a knife. Phosphorus melts at  $108^{\circ}$ , and inflames at  $148^{\circ}$ . At  $550^{\circ}$  it boils, and may be purified by distillation from a retort filled with hydrogen gas, receiving the product under water. Phosphorus is insipid and probably inodorous; but, in consequence of its oxidizement, it emits a feeble alliaceous odour of phosphorus, or hypophosphoric acid. When pure it is flexible, but the presence of 1-600th of sulphur renders it brittle. Its specific gravity is 1.77. Subjected to the rays of the sun, it acquires a red colour. If heated to  $155^{\circ}$  and suddenly cooled, it becomes black. Thenard, however, states that this change cannot be effected in phosphorus which has not been repeatedly distilled. He suggests it as possible, that the colour of phosphorus, when pure, is black; and that the colour which it usually assumes, may be due to the presence of hydrogen, which has been long known to be evolved, when phosphorus, in the usual state, is fused and subjected to the Voltaic current.

1124. Exposed to the air at ordinary temperatures, phosphorus combines slowly with oxygen, appearing luminous in the dark, but without any sensible evolution of heat. Less heat is requisite to cause the inflammation of phos-

phorus in atmospheric air than in oxygen; and less air is necessary in this last mentioned gas, in proportion as the pressure is reduced. When sprinkled with powdered sulphur, carbon, fluoride of calcium, carbonate of lime and various other bodies, and placed in a receiver from which the air is subsequently exhausted, phosphorus inflames. Professor Alexander D. Bache, who has much enlarged the list of substances capable of producing this result, has succeeded in inflaming phosphorus in an exhausted receiver by enveloping it in muslin, or in paper pierced with small holes. He conceives that, with the exception of bodies exercising a chemical affinity, as in the instance of sulphur, the substances associated with the phosphorus act mechanically, and have upon it no other effect than that of promoting its union with the oxygen remaining in the receiver. This opinion is corroborated by the fact that the removal of the air may be too rapid, or too complete, to produce the inflammation.

1125. Phosphorus may be crystallized from its solution in boiling naphtha, by gradual refrigeration. Like sulphur, phosphorus, in volatilizing, produces a feeble light, without entering into any chemical combination. Water in which phosphorus has been kept, oxygen being excluded, acquires the power of shining when agitated. The admission of air destroys this phosphorescent property. Phosphorus is oxidized by the action of nitric or nitrosonitric acid, and converted into phosphoric acid.

### *Experimental Illustrations of the Properties of Phosphorus*

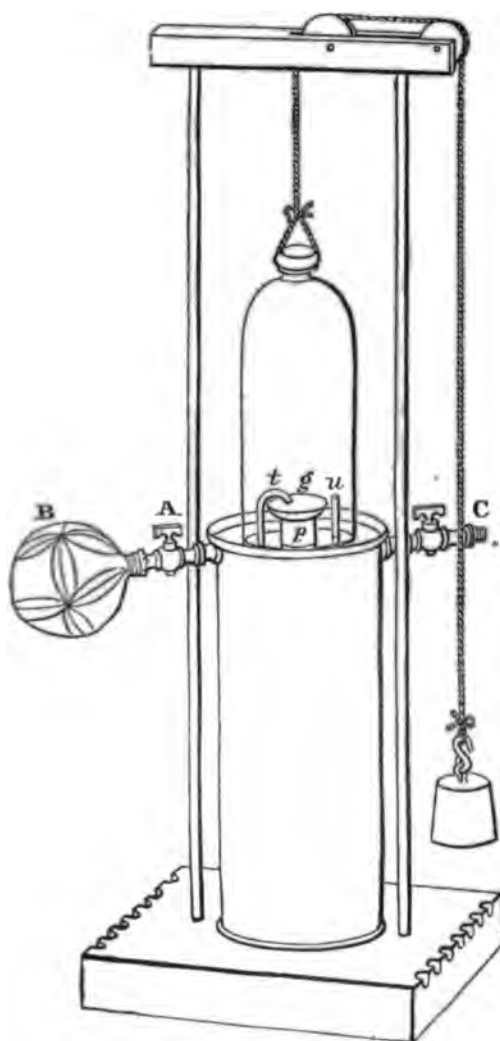
1126. Phosphorus exhibited, and inflamed by friction or a gentle heat. Luminous appearance in the dark. Combustion in oxygen, (654,) in nitrous, and nitric oxide, under hot water by a jet of oxygen, and by nitrosonitric acid (1131.)

1127. Anomalous combustion of phosphorus consequent to rarefaction.

#### *Combustion of Phosphorus in Nitric Oxide.*

1128. The backwardness of the gaseous oxides of nitrogen to part with their oxygen to substances, under circumstances in which it would be readily yielded by atmospheric air, has been already mentioned, and a method of illustrating it has been described. (969.) The opposite engraving represents an apparatus, which may be used to extend the illustration to nitric oxide, which, producing a corrosive fume, nitrous acid by admixture with oxygen, cannot be employed in apparatus requiring the aid of an air-pump, without corroding the metal of which such instruments are partially constituted. The apparatus in question is nearly the same as that used for

***Combustion of Phosphorus in Nitric Oxide.***







separation of nitrogen from atmospheric air. There are, however, in this, two lateral tubes; and the bell employed is without any cap or cock. The cock at *a*, which a gum elastic bag, supplied with oxygen gas, is attached, communicates a pipe, which descends close along the inner lateral surface of the cylindrical vessel till it reaches the bottom, then bends at right angles, and proceeds to the bottom of the vessel till it reaches the copper pipe in the axis of the vessel. It bends at right angles upwards, and ascends vertically in close contact with the pipe, till it reaches the copper cup, *g*, by which the pipe is surmounted. It is so recurved as to overhang and direct its orifice, *t*, downwards, into the cavity of the copper cup.

9. Another tube, *u*, proceeds from its junction with a screw and cock, *C*, on the side of the vessel, and descends to the bottom, rising again, like the tube mentioned, along the central pipe, till it reaches somewhat above the brim of the cup, where it terminates without a curvature. After the proper quantity of phosphorus has been placed in the cup, the atmospheric air may be allowed to enter from the bell glass through the cock, *C*, by sinking it into the water, with which the vessel must have been filled nearly to the brim. The air being expelled, communication made with a self-regulating reservoir of nitric oxide, by means of a flexible leaden tube attached to the cock for that purpose, the bell may be supplied with a quantity of this gas, sufficient to occupy about two-thirds of its capacity. The cock being then closed, and the communication with the reservoir interrupted, the hot iron must be introduced through the bore of the central pipe, *p*, till it reaches the cup. For this purpose, it is of course necessary that the apparatus should be upon a table with a suitable aperture, and of a height sufficient to allow one to enter the orifice of the pipe, *p*.

10. Although by the heat of the incandescent iron, the phosphorus will be ignited, no combustion will ensue, until, by opening a communication with the gum elastic bag, a small quantity of oxygen is allowed to enter. But no sooner is this allowed to take place, than a most brilliant and almost explosive evolution of heat and light ensues. A higher temperature is requisite to ignite phosphorus in nitric oxide.

#### *Reaction of Phosphorus with Nitroso-nitric Acid.*



1131. If into a tall tube of about an inch and a half in diameter, and fifteen inches in height, some strong nitric acid be introduced, and about five grains of phosphorus, a reaction will ensue, which is invariably energetic, and sometimes explosive. The phosphorus abstracting oxygen, the acid is converted into nitric oxide gas and nitrous acid vapour, which are copiously evolved, so as to fill the upper part of the tube, and overflow it with a beautiful red fume. Meanwhile, vivid flashes arise from the oxygenation of the phosphorus, and pieces of it are occasionally thrown up into the gas in the tube, where a vivid combustion ensues between the phosphorus, and the oxygen of the nitric oxide gas or nitrous acid.

1132. The residual nitric acid will be found intermingled with phosphoric acid.

1133. Latterly, in performing this experiment, I have surrounded the tube with a very stout glass cylinder, and another of wire gauze; as upon one occasion a violent explosion took place, which did much damage to my apparatus. If the phosphorus be reduced into small fragments, the risk of an explosion is increased. Heating the acid, before the addition of the phosphorus, ensures an explosive reaction.

#### *Application of Phosphorus to Eudiometry.*

1134. One of the most simple modes of ascertaining the quantity of oxygen in the air is to introduce into a graduated tube, standing over water, and containing 100 volumes of air, a stick of phosphorus, supported by a wire. The phosphorus slowly burns in the nitrogen, and, combining with the oxygen, condenses with it, and

causes a corresponding absorption of the water. When, by these means, the phosphorus is all removed, the quantity of nitrogen remaining will be known by the graduation. The difference between this quantity and 100, the number of parts taken, is the quantity of oxygen present.

*A Simple Atmospheric Eudiometer by Phosphorus.*



1135. If a cylinder of phosphorus be supported by a wire (as represented in the adjoining cut,) within a glass matrass, inverted in a jar of water, the portion of the included air will be gradually absorbed in order to determine the quantity of oxygen in it. We have only to ascertain the ratio of the gas absorbed, to the whole quantity of air included in the matrass at the commencement of the process.

1136. This object may be attained by weighing the matrass when full of water, and when containing only which rises into it in consequence of absorption. As the weight in the first case is the weight in the last, deducting the weight of the gas absorbed, so will 100 be to the number of parts of atmospheric air, which consist of oxygen and nitrogen.

1137. Again, the contents of the vessel may be covered by the sliding-rod gas measure, (936,) the absorption measured by introducing from the syringe, as much air as will compensate it. The whole content to the quantity which compensates the absorption, so is 100 to the quantity of oxygen parts of the atmosphere.

1138. If the neck of a vessel of this kind be divided into four equal parts, each division will represent a part of the whole capacity, the result may be known by inspection.

1139. Eudiometrical processes by the slow combustion of phosphorus are tedious, requiring many days to complete them, and consequently the aid of barometrical observations to ascertain and allow for any intervening changes in atmospheric pressure.

1140. It is alleged that nitrogen is enlarged one-fortieth of its bulk, by the phosphorus which it dissolves. This is to be deducted in estimating the residual gas.

1141. The action of the phosphorus may be accelerated by heat; but in this operation must be performed over mercury; and the manipulation will be troublesome and precarious.

1142. I have never in this way, obtained results comparable in accuracy and conformity, to those procured by the hydro-oxygen eudiometer. (140, &c.)

*Volumescopes for the Analysis of Atmospheric Air by Phosphorus.*

1143. A volumescopé has been described, (818.) for showing the diminution of bulk in five volumes of atmospheric air, consequent to the admixture of nitric acid. The same apparatus may, with some modification, be employed to show the contraction of volume resulting from the combustion of phosphorus. This object is attained by associating with the volumescopé, the apparatus employed for the combustion of phosphorus in oxygen. (654.) For this purpose, the volumescopé, instead of being situated over the pneumatic cistern, should be placed in a small tub, into the neck of which is inserted a tube, supporting, at the upper extremity, the cup for the phosphorus. The phosphorus being placed in the cup, and water in the tub, this is raised by an air-pump, until no more than five volumes of air remain in the cistern. The phosphorus is then ignited by means of a red-hot iron, and the contraction of volume is conducted as already described. (922.) As soon as the expansion resulting from the heat of the combustion ceases, it will be seen that a little more than one volume of the five has been condensed.

COMPOUNDS OF PHOSPHORUS WITH OXYGEN.

1144. These compounds are four in number; one is phosphoric oxide, and three acids, hypophosphorous, phosphorous, and phosphoric.

*phorous*, and *phosphoric acid*. Their composition is as follows:—

Three atoms of phosphorus, equivalent 48,	{	with one atom of oxygen, equivalent 8, form oxide of phosphorus, equivalent 56.
	{	with one atom of oxygen, equivalent 8, form hypophosphorous acid, equivalent 40.
Two atoms of phosphorus, equivalent 32,	{	with three atoms of oxygen, equivalent 24, form phosphorous acid, equivalent 56.
	{	with five atoms of oxygen, equivalent 40, form phosphoric acid, equivalent 72.

#### *Of Oxide of Phosphorus.*

1145. When phosphorus, melted under hot water, is subjected to a jet of oxygen from a tube with a capillary orifice, oxide of phosphorus and phosphoric acid are produced. The acid dissolves, and the oxide, being at first suspended in the water, subsides subsequently in red flakes. This oxide is insipid and inodorous. It is not luminous in the dark, even when rubbed. At a heat a little below redness in close vessels, it is decomposed into phosphoric acid and phosphorus. If the air be admitted, phosphoric acid is the sole product. The oxide of phosphorus takes fire spontaneously in chlorine, producing the perchloride of phosphorus and phosphoric acid. It is inflamed by the action of nitric acid. With chlorate of potash it explodes violently; also with nitrate of potash previously warmed. The white matter with which phosphorus becomes coated when kept in water, and which is generally supposed to be a *hydrate* of the *oxide*, is stated by Thenard to be a *hydrate* of *phosphorus*.

#### *Production of Oxide of Phosphorus experimentally illustrated.*

1146. Production of oxide of phosphorus, by the reaction of oxygen with that substance, while in fusion under hot water.

#### *Of Hypophosphorous Acid.*

1147. This acid is obtained by precipitating the baryta from an aqueous solution of hypophosphate of that base. The acid remaining in solution, may be so concentrated by evaporation as to become a vivid liquid, highly acid, and even crystallizable. It is an energetic deoxidizing agent, and forms numerous salts, all of which are soluble in water, whereas several of the phosphates are insoluble.

#### *Of Phosphorous Acid.*

1148. This acid has been generally considered as the product of the slow combustion of phosphorus with atmospheric oxygen; but Thenard alleges that this product is a peculiar acid, intermediate in its degree of

oxidation between phosphorous and phosphoric acid, and to which he has given the name of *hypophosphoric acid*. Phosphorous acid may be procured by passing vaporized phosphorus over corrosive sublimate heated in a tube. Chloride of phosphorus results, which, by reaction with water, produces chlorohydric and phosphorous acids. The chlorohydric acid, being more volatile, may be expelled by heat.

1149. Phosphorous acid is a colourless, inodorous, crystalline substance, possessing a pungent taste, and reddening litmus paper. Like hypophosphorous acid, it possesses powerful deoxidizing properties.

### *Of Phosphoric Acid.*

1150. *Preparation.*—Phosphoric acid may be obtained by adding sulphuric acid to phosphate of baryta suspended in water. The sulphuric acid unites with the baryta, forming an insoluble salt, which precipitates while the phosphoric acid remains in solution. When phosphorus is gradually added to nitric acid, phosphoric acid is generated, and remains mingled with the residual nitric acid.

1151. *Properties.*—Phosphoric acid is an inodorous, colourless, viscid liquid, possessing in a high degree the property of reddening litmus. It cannot be obtained in a state of liquidity free from water. When exposed to a red heat and afterwards cooled, it forms a transparent brittle glass. This fusion should be effected in a platinum crucible; since phosphoric acid, when heated to redness, attacks either glass or porcelain. The acid, if examined after this exposure to heat, is found, although its composition remains the same, to have acquired new properties. On this account, the name of *paraphosphoric* has been given to it; while the term phosphoric is applied to designate the acid in the state first described. Nitrate of silver yields with phosphoric acid a yellow precipitate; with paraphosphoric acid a white one. Albumen is coagulated by the latter, but not by the former.

1152. Solid paraphosphoric acid, when exposed to the air, deliquesces, and is in a few days converted into phosphoric acid. The same change is produced in a short time by boiling water. The solid white flakes which are obtained during the quick combustion of phosphorus with oxygen, consist of paraphosphoric acid. It may likewise be produced by fusing the biphosphate of soda, which by these means is converted into a paraphosphate. Mr. Graham, who has made a number of interesting experiments on this subject, states that the acid which is con-

mixed in phosphoric of is a third species of  
 others, but in composition with the  
 the name of *pyrophosphoric*. To this species he has given

1153. To bodies which different  
 containing the same n atoms of t s  
 ments, and having the it, t ter  
 meric has been applied. us, no, a  
 and pyrophosphoric acid e to

### *Of the Chlorides of Phosphorus.*

1154. It has been shown, (983,) that phosphorus burns spontaneously in chlorine. If the chlorine be in excess, the perchloride is formed; if the phosphorus be in excess, the sesquichloride is obtained. The *sesquichloride* is a transparent, colourless, fuming, inflammable liquid, heavier than water, and having a disagreeable smell. When brought into contact with water, a reciprocal decomposition takes place, and chlorohydric and phosphorous acid are produced. The *perchloride* is a white, crystalline, inflammable body, which is converted into vapour at a temperature much below  $212^{\circ}$ . It forms a neutral compound with ammonia, and its vapour is alleged to redden dry litmus paper. Hence, by some chemists, it is considered as an acid. I doubt whether litmus paper is ever reddened by an acid, unaided by water. The perchloride and water decompose each other, forming phosphoric and chlorohydric acid. The chlorine bears the same ratio to the phosphorus in these chlorides, as the oxygen bears to the phosphorus in phosphorous, and phosphoric acid.

### *Of the Bromides and Iodides of Phosphorus.*

1155. The *sesquibromide* is a yellow fuming liquid; the *perbromide*, a crystalline volatile solid. In their reaction with water and composition, they agree with the chlorides of phosphorus. Iodine appears to combine with phosphorus in almost every proportion. There are, however, at least two definite combinations, which correspond in composition with the chlorides and bromides.

### *Of the Sulphides and Selenides of Phosphorus, commonly called Sulphurets and Seleniurets.*

1156. When phosphorus is melted with sulphur, or when sprinkled with it, and placed in a receiver from which the air is subsequently withdrawn, (1124,) a sulphide of phosphorus is formed. This sulphide may consist of various proportions of its ingredients, according to the circumstances under which it is produced. Sometimes it is liquid, sometimes solid.

1157. Selenium, like sulphur, combines with phosphorus in almost every proportion. The sulphides and selenides of phosphorus are decomposed by water.

1158. The incorporation of sulphur with phosphorus, when effected by heat, is sometimes productive of explosion; and the resulting mass is spontaneously inflammable in the air; being the sole active ingredient in some friction matches.

## COMPOUNDS OF PHOSPHORUS WITH HYDROGEN.

*Of Protophosphuretted Hydrogen.*

1159. Protophosphuretted hydrogen may be obtained by heating a concentrated solution of phosphorous acid, or by adding phosphorus to the materials for generating hydrogen.

1160. *Properties.*—It is a colourless, inflammable gas, with an odour similar to that produced by the combustion of arsenic. Under the ordinary pressure of the atmosphere, protophosphuretted hydrogen does not combine spontaneously with oxygen; but, if the pressure be reduced about one-third, combustion ensues.

1161. On meeting with oxygen, this gas becomes luminous in the consequence of the slow combustion of the phosphorus; though the heat evolved is inadequate to inflame the hydrogen. If the process for producing the philosophical candle, (806,) be repeated with the addition of some comminuted phosphorus to the materials, protophosphuretted hydrogen will be generated, and, escaping into the air, will produce a jet luminous in the dark.

*Of Perphosphuretted Hydrogen.*

1162. Perphosphuretted hydrogen may be produced by the reaction of chlorohydric acid with the phosphuret of calcium, which is obtained by projecting lime to the vapour of phosphorus at a bright red heat in a porous or coated glass tube. The gas may also be evolved by heating in a retort 75 grains of phosphorus, 1500 of slacked lime, with 4 ounces of water, 50 grains of caustic potash, and 40 of phosphorus, moistened by 60 of water. The phosphorus should be added first, and the potash last. The heat which it evolves, contributes to the heat required for the operation. The body of the retort should be filled with hydrogen, or a few drops of ether should be added, to prevent the first portions of the gas from inflaming with the atmospheric oxygen of the retort. By its affinity for the phosphorus, and the metal of the phosphuret, the oxygen of the water is separated from the hydrogen, which, while nascent, unites with a portion of the phosphorus, and forms perphosphuretted hydrogen.

1163. The following cut represents the apparatus usually employed for obtaining perphosphuretted hydrogen.



1164. The beak of the retort being depressed below the surface of the liquid in the dish, the gas is evolved and passes into the air.

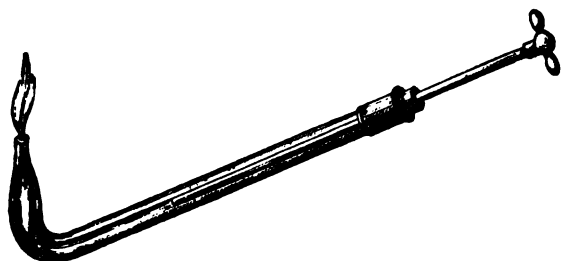
mercury, each bubble as it escapes into the atmosphere, explodes. It produces at the same time a dazzling flash, which is transformed into a beautiful wreath of smoke, consisting of aqueous vapour and phosphoric acid, created by the oxygenation of the hydrogen and phosphorus. Each wreath, as it rises, expands in diameter, and, when the bubbles succeed each other quickly, a series of them may be seen in the air at the same time.

1165. *Properties.*—Perphosphuretted hydrogen is a colourless gas, possessing an alliaceous smell, and a bitter taste. Water dissolves it in small quantity, forming a yellow solution, which has a bitter taste, and a smell resembling that of the gas. When this gas is brought in contact with oxygen, or atmospheric air, it explodes with a loud noise and a vivid flash; being converted into phosphoric acid and water. The same mixture, in narrow tubes, undergoes a similar change slowly, and without the evolution of heat and light.

1166. Perphosphuretted hydrogen may be decomposed either by heat, by the electric spark, or by the rays of the sun. Professor Rose considers protophosphuretted and perphosphuretted hydrogen as isomeric, and of course similar in composition, though different in properties. If the opinions of Rose are correct, one should be called phosphuretted hydrogen, the other paraphosphuretted hydrogen. (1153.)

1167. Chemists do not agree in their statements respecting the composition of the compounds of hydrogen with phosphorus.

*Method of exhibiting the Inflammation of Small Portions of Gas.*



1168. This figure illustrates an advantageous employment of the sliding-rod eudiometer, in exhibiting the spontaneous combustion of phosphuretted hydrogen, the splendid colour of the flame of cyanogen, and other experiments, where the combustible character of a small quantity of gas is to be shown.

1169. For the experiments in question, the instrument is charged, agreeably to the mode already described in the case of the eudiometers, by introducing the apex into any bell glass or other vessel holding the gas, and drawing out the rod; by which a portion of the gas, equivalent in bulk to the part of the rod withdrawn, enters the receiver of the eudiometer through the hole in the apex. The receiver being then removed from the bell glass, and held up in a position favourable for observation, the rod is slowly returned into its tube, so as to expel the gas in a jet suitable for inflammation. In the case of perphosphuretted hydrogen, the gas burns spontaneously as soon as it escapes from the apex. In the case of other inflammable gases, inflammation is produced by the flame of a taper.

## SECTION IV.

## OF CARBON.

1170. Nature presents us with the most beautiful and purest specimens of this substance. The diamond is pure carbon. When equal weights of charcoal and diamond are severally exposed to the focus of a powerful lens in oxygen gas, included in different bell glasses, they are both converted into carbonic acid, from which, by ignition with potassium, carbon may be precipitated.

1171. Carbon is very abundant in nature, in the various kinds of fossil coal, from anthracite or plumbago, in which it is nearly pure, to the variety called candle, or cannel coal, which abounds with bitumen. In bituminous coal there is much hydrogen. Carbon pervades vegetable and animal matter as an essential element. It is, especially, a constituent of the fibres of wood.

1172. Until of late, plumbago was considered as a chemical compound of iron with carbon. Berzelius alleges it to be carbon mingled, but not combined, with iron and other impurities.

1173. I ascertained that anthracite, when completely burned in oxygen gas, produced no diminution of volume, the products being water and carbonic acid. I infer, therefore, that the combustible portion of this coal consists almost solely of carbon, united with hydrogen and oxygen in the proportion for forming water. It may, in fact, be deemed an hydrate of carbon.

1174. *Preparation.*—In the laboratory, charcoal is obtained, sufficiently pure, by heating wood intensely in close vessels. In the large way, it is procured by igniting large quantities of wood, so covered with earth, that the access of air may be at first controlled and afterwards prevented.

1175. Coke is obtained from bituminous coal, by a process analogous to that employed for obtaining vegetable charcoal, which it resembles in chemical, though not in mechanical properties.

1176. *Properties.*—Carbon is inodorous, insipid, and usually black. Charcoal of wood is one of the best radiators, and worst conductors of heat. There is reason for believing this peculiarity to result from its excessive poro-



ity; as in the form of anthracite, carbon conducts heat better, and probably radiates it worse. Charcoal is highly susceptible of galvanic ignition.

1177. Next to the metals, charcoal is the best conductor of electricity. It appears, from the experiments of Professor Silliman, that charcoal, when exposed to the influence of a powerful Voltaic series, is volatilized, so as to be transferred from the positive to the negative pole, on which it forms a projection.

1178. Charcoal, when intensely ignited without access of air, becomes denser, harder, and a better conductor of heat. Substituting animal products for those of vegetation, in the usual process of carbonization, *animal charcoal* is obtained. It does not, like the coal of vegetable substances, retain the form of the bodies from which it may be procured, and is replete with cavities, created by the escape of the gaseous elements associated with it in the organic state. It has a grayish-black colour, and a brilliancy resembling that of plumbago. Carbon is precipitated in various forms from coal gas; among others, in that of long brittle filaments, associated in tufts, resembling locks of hair.

1179. The specific gravity of carbon, in the state of diamond, or in that of common charcoal, when examined in the pulverulent form, so that the result shall not be affected by the numerous cavities existing in it when in mass, is about 3.5. The apparent lightness of charcoal is caused by its porosity. The specific gravity of anthracite does not exceed 1.6; that of plumbago is 2.32; yet they are both much more compact than charcoal, and, in proportion to the space occupied by them in mass, obviously much heavier.

1180. Carbon, under some circumstances, appears to have a transcendent affinity for oxygen. In its ordinary state it requires a temperature above redness, in order to exhibit this affinity—in other words, to burn. In proportion as it becomes denser, we find it more difficult to ignite; in proportion as it may be more minutely divided, or approaches a state of extreme porosity, it is rendered more susceptible of ignition. Thus the susceptibility of ignition increases from the diamond to tinder in the following order:—Diamond, plumbago, anthracite, coke, charcoal of hard wood, charcoal of soft wood, tinder. In some

forms, and when mixed with iron, as when obtained by carbonizing Prussian blue, or tanno gullate of iron, it takes fire spontaneously at ordinary temperatures.

1181. According to Despretz, carbon, during its combustion, evolves sufficient caloric to melt one hundred and five times its weight of ice. It is not to be inferred that this is true of carbon in all its forms. Berzelius alleges that the same degree of heating power is not possessed by every kind of charcoal; some of its forms, according to him, producing much more heat in burning than others. This I should not believe without conclusive evidence.

### *Of the Decolorizing and Disinfecting Power of Charcoal.*

1182. Carbon, as procured from organic products, especially animal matter, displays a great power to combine with and precipitate colouring matters. Hence it is extensively used in the refining of sugar, and generally in chemical processes, in which the objects of research are entangled with colouring matter. This power is not inherent in elementary carbon, but appears to be due to its previous associations, or to some peculiarity of arrangement, derived from the process of carbonization.

1183. Animal charcoal is much more efficacious than that derived from vegetables. The carbonaceous mass, obtained by igniting blood with carbonate of potash, appears to have the greatest efficacy. That the presence of an alkali during the ignition contributes to the effect, seems to justify the conjecture that cyanogen, the generation of which, in combination with the alkali, is a necessary concomitant, has some agency in the process. Charcoal is a powerful antiseptic, operating efficiently in preserving water or meat from putridity. Moreover, water rendered extremely foul, as that from the public sewers, may be purified by filtration through pulverized charcoal. In fact, filters are now extensively manufactured, in which charcoal is the most efficient and only chemical agent employed. The gravel, sand, and sponge, usually associated with it, act mechanically.

### *Of the Power of Charcoal and other Substances to absorb Aëriform Fluids.*

1184. Charcoal, which has, in a state of ignition, been submerged in mercury, on being introduced into gaseous substances, condenses into its

is a large quantity of the surrounding æriform matter, whatever it may

The quantity condensed varies with the gas, from 90 times the bulk of charcoal, as in the case of ammonia, to 1.75 times its bulk, as in the case of hydrogen. During their absorption, the gases give out heat, and more in proportion to the rapidity with which the condensation is effected; and if, on the other hand, by exposure within an exhausted receiver, gas be evolved, cold is produced. Charcoal, thus deprived of gas, rejects any gas exposed to it, as greedily as if recently ignited.

1185. This faculty of absorbing gaseous substances, is impaired by humidity, which charcoal is prone to absorb in the form of vapour, afterwards dissolving it into the state of water. Water partially displaces the gases previously absorbed.

1186. The æriform fluids, absorbed by charcoal, are expelled by heat applied, with the exception of sulphuretted hydrogen and oxygen. The former deposits sulphur, and the latter is gradually converted into carbonic acid. The absorption of this last mentioned principle continues for some time, but, in quantity, has not been found to exceed 14 times the volume of carbon. In a rarefied medium, charcoal absorbs less in weight, but more in volume; so that the increased resistance of the gas, arising from a diminution of pressure, counteracts, to a certain extent, the power of the charcoal to condense into its pores a certain weight. The power of absorption varies in a degree with the number and minuteness of the pores existing in charcoal; of course, it varies with the wood by which it is yielded. Charcoal of box-wood is pre-eminent in absorbing power; that furnished from woods of a lighter kind is very inferior in this power. Plumbago and graphite have no capacity, even after ignition, to absorb gases.

1187. In the property of absorbing æriform fluids, charcoal is not singular. De Saussure ascertained that different porous minerals, and many kinds of wood, also silken and woollen stuffs, absorb many times their volume of gas.

1188. When porous bodies are placed in a mixed atmosphere of various gases, they are absorbed in proportion to their reciprocal attractions, and the force exercised by the pores of the substances employed. A mixture of oxygen with hydrogen or carbonic acid, is more copiously absorbed than oxygen when alone; yet by heat or exhaustion they are liberated without diminution. Nevertheless, sulphuretted hydrogen and oxygen, when acted on by charcoal, produce water, sulphur being deposited.

1189. The absorption of moisture by charcoal and other porous bodies has long been noticed. On this account, it is difficult to weigh such bodies without an increase of their weight, even when they are placed in the scale while red-hot. Those æriform fluids are absorbed to the greatest extent, which are capable of assuming the liquid state. These facts explain the augmentation in weight received by charcoal exposed to the air, which amounts to between ten and twenty per cent.

1190. I have devoted more space to this subject, because it illustrates a property which otherwise might not be sufficiently considered. It forms a peculiar instance of mechanico-chemical agency, if I may be allowed to use a new word to express the idea. Without the porous or cellular structure which it possesses in the form of charcoal, carbon is not endowed with either disinfecting, absorbing, or colour-removing powers; and yet it is evident that the carbon acts in charcoal by a species of chemical affinity, unaided by which the cellular structure would be inefficient in the cases under consideration. As respects the transmission of contagious

or infectious effluvia, the absorbing power of porous bodies merits a I believe that the carbonaceous matter, evolved during the burning of actually neutralizes those fetid emanations which it is employed to in the chambers of the sick.

#### COMPOUNDS OF CARBON WITH OXYGEN.

One atom or one volume of carbon, equivalent 6,	{	with one atom or half a volume of oxygen equivalent 8, forms one atom or one volume of <i>carbonic oxide</i> , equivalent 14, with two atoms or one volume of oxygen equivalent 16, forms one atom or one volume of <i>carbonic acid</i> , equivalent 22.
---	---	--

1191. Two atoms or volumes of carbon, equivalent 12, with three atoms or one and a half volumes of oxygen equivalent 24, form one atom of *oxalic acid*, equivalent 36.

1192. Two other compounds of carbon with oxygen are alleged to exist; one called *mellitic*, the other *croconic*. The former contains four atoms of carbon to three of oxygen; the latter five of carbon to four of oxygen.

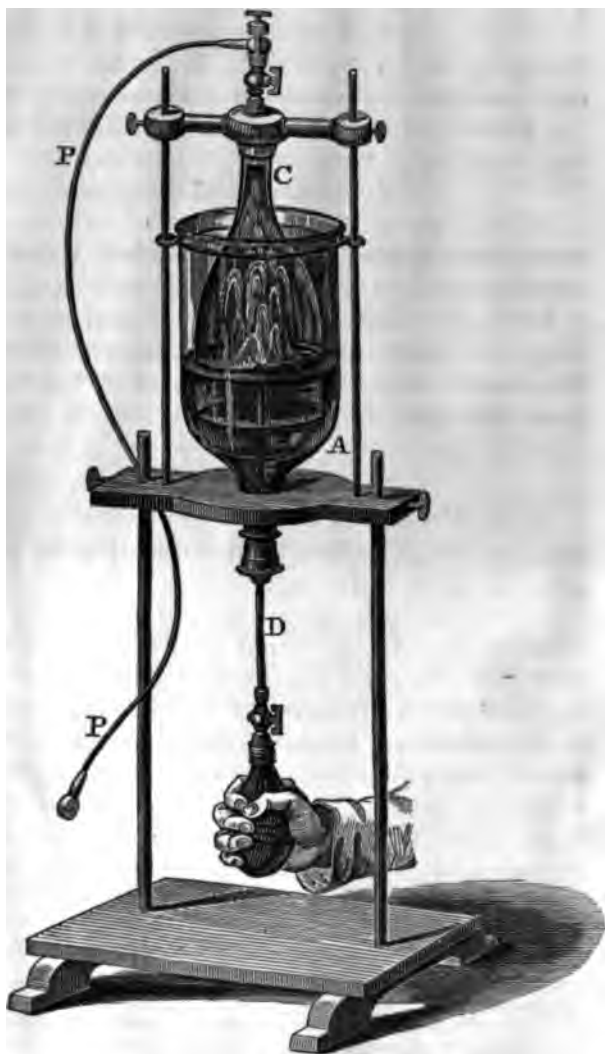
#### *Of Carbonic Oxide.*

1193. *Preparation.*—This compound is produced by the combustion of carbon with an inadequate supply of oxygen; or when bodies containing carbonic acid are decomposed with certain substances having an affinity for oxygen. Thus it may be procured by heating carbonate of iron with iron filings. The best process, however, for obtaining carbonic oxide in a state of purity, is to heat five parts of concentrated sulphuric acid with one of oxalic acid. The sulphuric acid, which, being deprived by the sulphuric acid of the oxygen which is essential to its existence, is resolved into carbonic oxide and carbonic acid. The latter gas may be removed by lime-water, leaving the carbonic oxide in a state of purity.

#### *Apparatus for separating Carbonic Acid from Carbonic Oxide, by means of Lime-water.*

1194. This apparatus is represented by the opposite engraving. Lime-water is introduced in sufficient quantity into the inverted bell glass, another small glass, C, is supported within it as represented in the engraving. Both of these glasses have perforated necks. The inverted bell is furnished with a brass cap and stuffing box attached to it, through which the tube, D, of copper, slides. About the lower end of this tube, the neck of a gum elastic bag is tied; so that the cavity of the bag may communicate with that of the tube. The neck of the bell is furnished with a cap and cock, surmounted by a gallow's screw, by which the leaden pipe, P P, with a brass knob at the end suitably perforated, may be fastened to it, or removed at any moment. Suppose this pipe, by aid of the brass knob at the other extremity, to be attached to the perforated neck of a tall bell glass filled with water upon a shelf of the pneumatic cistern: on

***Apparatus for separating Carbonic Acid from Carbonic Oxide, i  
Means of Lime-water.***



(Page 224.)



niation between the bells, the water will subside in the tall bell glass over *a*, and the air of the bell glass, *C*, being drawn into it, the lime-water will and partially occupy the space within the latter. As soon as this is effected, the cocks must be closed, and the tall bell glass replaced by a small one of water, and furnished with a gallows screw and cock. This bell being at the knob of the lead pipe, to which the tall bell had been fastened before, *atmos* is ready for use. I have employed it in the new process for obtaining carbonic oxide from oxalic acid, by digestion with sulphuric acid in a glass retort. The product consists of equal volumes of carbonic oxide and carbonic acid, being received into a bell glass, communicating, as above described, by a pipe bell glass, *C*, may be transferred into the latter, through the pipe, by open-cocks. As the gaseous mixture enters the bell, *C*, the lime-water subsides. As a sufficient quantity of the gas has entered, the gaseous mixture, by means of an elastic bag and the hand, may be subjected to repeated jets of lime-water, depurated of all the carbonic acid. By raising the liquid in the outer bell, carbonic oxide may be propelled through the cock and lead pipe, into the vessel to which it may be desirable to have it transferred.

5. *Properties of Carbonic Oxide.*—Carbonic oxide is colourless, insipid gas, indecomposable by heat or electricity, and incapable of reddening litmus. Its specific gravity is 0.9727. It does not support combustion, and is inactive to life. It burns with a feeble blue flame, and, combining with oxygen, is converted into carbonic acid. Platinum sponge, a mixture of oxygen and carbonic oxide, is gradually changed into carbonic acid.

### *Experimental Illustrations.*

6. Carbonic oxide gas, evolved from oxalic acid by the process above-mentioned, and collected in bell glasses inverted in water. Combustion and detonation of it with oxygen, effected by means of a sliding-rod eudiometer, or gas escape. Subsequent absorption of the resulting carbonic acid by lime-water, shown.

### *Of Carbonic Acid.*

7. The proportion of this gas, existing in the atmosphere, is much less than was formerly supposed; being, according to some experiments of Thenard, not more than a hundredth part. It is this portion, however, that produces the pellicle on lime-water, during its exposure to the atmosphere, and which, under like circumstances, by combining with the alkalies, enables them to effervesce with acids. Carbonic acid is incessantly a product of combustion and the respiration of animals. It is a principal ingredient in the formation of marble and limestone.

8. *Preparation.*—Carbonic acid may be evolved from

any carbonate by heat or by acids. It is usually procured for the impregnation of water, by the superior affinity of sulphuric acid for the lime in marble. Excepting that it is more costly, chlorohydric acid is preferable for this purpose; as the chloride of calcium, being very soluble, does not, like the sulphate, clog the vessels.

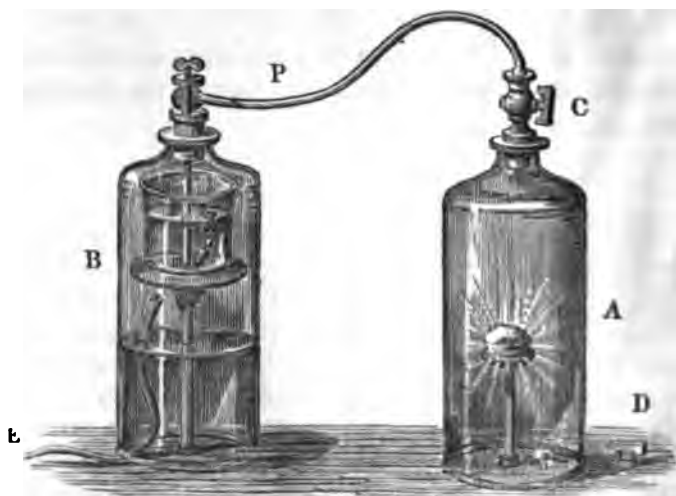
1199. Carbonic acid is evolved copiously during the vinous fermentation.

1200. The process and the self-regulating reservoir, already described, (796, &c.) may be resorted to for carbonic acid, substituting lumps of marble for zinc. The best materials for the evolution of this gas, agreeably to my experience, are chlorohydric acid and calcareous stalactites, or clam shells.

1201. Carbonic acid might be procured at a trifling cost, by drawing, by the aid of a suction pump, the effluvia of burning charcoal through water to deprive it of dust, and then forcing it into the cavities in which its presence may be desirable.

1202. This process for the production and employment of carbonic acid, generated by the combustion of charcoal, is illustrated in the small way by the following engraving and description.

*Combustion of Charcoal or other Combustibles in Oxygen Gas.*



1203. The preceding cut represents an apparatus which I have contrived for exhibiting the combustion of charcoal, or other combustibles, in oxygen gas. Two large glass bells, A, B, each furnished with a tubulure at the apex, are associated by



as of the pipe, P, which, in one of the bells, B, communicates with a tube, extending about five inches within the bell, below its neck, so as to reach into some lime-water, or an infusion of litmus, contained in a glass vessel, resting on a stand, represented in the figure. The wooden stand which holds the glass vessel, and the iron stand which supports the coal in the bell, A, must be previously placed on a shelf of the pneumatic cistern, as represented in the cut; so that A, when lighting the coal, may be over the mouth of the cock, D, which communicates with one of the gas holders, situated under the shelves of the pneumatic cistern, which, in this experiment, should be filled with oxygen.

M. Into the bell glass in which the vessel is placed, a pipe from the suction pump or hydrostatic blowpipe is made to enter, and reach nearly to the stand. The apparatus having been prepared thus far, the bells must be lifted so as to permit the coal to be put upon the iron stand, as represented in the figure. As soon as the apparatus is restored to their previous situations, the suction pump must be put into action, and the cock, D, of the gas holder, containing the oxygen, opened; so as to allow a current of the gas to have access to the coal, by replacing the air, which is withdrawn by the pump through the pipes, P and E. The coal burns splendidly; as the oxygen becomes saturated, it is drawn off by the suction pump, being carried, in its way from A to B, to pass through the liquid in the vessel, into which it descends the tube proceeding from A. If the liquid be water tinged with litmus, it becomes red by the action of the carbonic acid: if it be lime-water, a copious white precipitate will appear.

1205. *Properties of Carbonic Acid.*—It is a colourless gas, with a pungent smell and an acid taste. Water takes up its own bulk of this gas, whatever may be its density. It combines with earths, alkalies, and metallic oxides, forming compounds which are insoluble. Hence it precipitates lime-water, barytic-water, and solution of acetate of lime. Litmus is reddened by this acid. It destroys life and extinguishes flame, but is not insalubrious to breathe when much diluted with air.

1206. Carbonic acid is very antiseptic. When concentrated in water it is grateful to the stomach. Potassium burns in this gas, absorbing oxygen and precipitating carbon. Plants probably absorb it, retain its carbon, and give out its oxygen. The respiration of animals tends to compensate this change, by carbonizing the oxygen of the air.

1207. Carbonic acid is heavier than atmospheric air, its specific gravity being 1.5239. At the temperature of 31° F., and under a pressure of forty atmospheres, it condenses into a colourless liquid.

### *Experimental Illustrations.*

1208. Evolution of the gas shown; also its property of extinguishing a candle. That it differs from nitrogen, made evident by means of lime-water. Litmus, reddened by carbonated water, and restored to its original colour by boiling.

## 1209. Analysis of mixtures containing the gases means of the sliding-rod eudiometer and lime-water.

*Apparatus for showing some of the distinguishing Properties of Carbonic Acid*



1210. Having introduced in the three-necked bottle, represented adjoining figure, one or two ounces of carbonate of ammonia, add about as much nitroso-nitric acid. (10) active effervescence will ensue, from the expulsion of the carbon from the ammonia, by the stratum of the nitric acid. At the time, sufficient fume will be given to make it evident how far the are occupied by the gas, to the sion of atmospheric air. By these the movements of the carbonic will be recognised as ascending upper vessel, which it will finally overflow through the crevice between the brim and cover.

1211. The cover being removed, a lighted candle will cease to burn lowered into the fume indicating space occupied by the gas. This will comprise the whole cavity of the vessel, so long as the aperture is closed; but, on removing the cover, this aperture, the gas will flow out the stream, marked by the ascending fume, will be seen descending towards the table, and will extinguish the flame of a candle if made to enter it; or, it may be received into

so as to arrest the combustion of a taper introduced into it, or upon which the tents of the mug may be poured. Under these circumstances, a taper will burn where within the vessel, V, if it be not below the aperture, A, above which is not now seen to extend itself. But if one of the orifices of the bottle be closed, the carbonic acid will be found entirely to desert the upper vessel.

1212. It will thus be made evident that this gas, from its greater specific gravity, in the atmosphere, some of the habitudes of liquids; while its incapacity to support combustion will be demonstrated.

1213. The specific gravity of carbonic acid being rather more than that of atmospheric air, it does not speedily leave any cavity in which it may be introduced. It is on this account that persons often perish on the wells.

### *Impregnation of Water with Carbonic Acid.*

1214. The process by which water is impregnated with carbonic acid, is easily understood from the following engraving.

1215. A condenser, A, is fastened at bottom into a block of brass, which is furnished with a conical brass screw, by means of which it is easily attached to the floor. In this brass block are cavities for the two valves, one opening from the pipe, B, the other outwards towards the pipe, C. The pipe, B, communicates with a self-regulating reservoir of carbonic acid.

1216. The gas which the condenser draws in from the reservoir, is forced by the other pipe into a strong copper vessel, in which the water is situated, and is represented in the figure, as if the front part were removed, in order to expose the inside to inspection.

1217. If the vessel and its contents be thoroughly exhausted of air before the impregnation is commenced, the water will take up as many times its bulk of gas as the pressure employed exceeds that of the atmosphere.

1218. When duly saturated, the water may be withdrawn at pleasure by means

the syphon, D, of which one leg descends from the vertex of the vessel to the bottom, while the other is conveniently situated for filling a goblet.



### *Of the Liquefaction and Solidification of Carbonic Acid.*

1219. It has been shown that the extrication of carbonic acid from a base, may be checked by the pressure consequent to confinement, (242,) and it has been mentioned that Faraday obtained this acid in a liquid state, by causing the materials for the generation of it to react within a glass tube, sealed hermetically after their introduction. Subsequently, the liquefaction of this acid was accomplished on a much larger scale by Brunel; and in 1836, thirteen years after the date of Faraday's observations, Thillorier caused not only the liquefaction, but the solidification of the acid. Without any other knowledge than that afforded by brief notice, or verbal information conveyed by travellers, my friend, Dr. Mitchell, was quite successful in the repetition of the processes of Thillorier. The production of the solid acid is dependent on the same principles as the congelation of water in the cryophorus and in Leslie's experiment. (309, &c.)

1220. The pressure requisite to retain carbonic acid in a state of liquidity, is at  $4^{\circ}$  below zero, 26 atmospheres; at  $32^{\circ}$ , 36 atmospheres; at  $86^{\circ}$ , 75 atmospheres. (196.) Its specific gravity is, at that temperature, about 830. The density of the gas which occupies the cavity above the liquid portion of the acid, is 130 times the density of that which it has at the mean barometric pressure of 30 inches of mercury.

1221. Liquid carbonic acid does not combine, nor even mingle, with water or fixed oils; but, under the requisite pressure, combines readily with ether, alcohol, naphtha, or oil of turpentine. It may be decomposed by potassium, but not by zinc, iron, or other metals proper.

1222. One of the most interesting properties of the acid, is that intense cold produced by its assuming the æriform state, to which allusion has been made. A jet of it depressed a thermometer to  $130^{\circ}$  below zero, F. The cold by which the acid is frozen, or in other words, its freezing point, is estimated at  $148^{\circ}$  below zero, F. According to Mitchell, one drachm of

solid acid is yielded by each ounce of the liquid. I will here give Dr. Mitchell's description of this wonderful product of chemical art, in his own words:\*

1223. "The porosity and volatile character of the solid renders its specific gravity of difficult ascertainment. When recently formed it is about the weight of carbonate of magnesia, and when strongly compressed by the fingers, its density is nearly doubled. Solid carbonic acid is of a perfect whiteness, and of a soft and spongy texture, very like slightly moistened and aggregated snow. It evaporates rapidly, becoming thereby colder and colder; but the coldness produced seems to steadily lessen the evaporation, so that the mass may be kept for some time. A quantity weighing 346 grains lost from 3 to 4 grains per minute at first, but did not entirely disappear for 3 hours and a half. The natural temperature was  $76^{\circ}$ — $79^{\circ}$ . The solid is most easily kept when compressed and rolled up in cotton or wool. Its temperature when newly formed is not exactly ascertainable because it is immediately lowered by evaporation. Thillorier seems to have entertained the opinion that the greatest degree of cold was created at the time of the formation of the solid. In my experiments a constant decrease of temperature was observed; which was accelerated by a current of air, or any other means of augmenting evaporation. At its formation, the carbonic snow depresses the thermometer to about  $-86^{\circ}$ . If it be confined in wool or raw cotton, its cooling influence is retarded; if it be exposed to the air, especially when in motion, the thermometer descends much more rapidly; and under the receiver of an air pump, the effect is at its maximum. The greatest cold produced by the solid carbonic acid in the air was  $-109^{\circ}$ , under an exhausted receiver  $-136^{\circ}$ , the natural temperature being at  $+86^{\circ}$ .

1224. "The admixture of sulphuric ether so as to produce the appearance of wet snow, increased the coldness, for the temperature then fell, under exhaustion, to  $-146^{\circ}$ ,\* a degree of cold which we were not able to exceed by means of any variation of the experiment. That result is most easily obtained by putting about two fluid drachms of ether into the iron receiver before charging it. A compound liquid may be thus formed which yields a snow in less quantity, but of a more facile refrigeration. Alcohol may replace ether in either mode, but with less decided effect. In the air the alcoholic mixture fell to  $-106^{\circ}$  and remained stationary. By blowing the breath on it, it fell to  $-110^{\circ}$ . Left to itself it rose slowly to  $-106^{\circ}$ ; but on being placed under an exhausted receiver fell to  $-134^{\circ}$ .

1225. "Every attempt to wet the carbonic solid with water, failed, so that no estimate of its relative effects could be made.

1226. "The experiments resulting from the great coldness of the new solid, were very striking. Mercury placed in a cavity in it, and covered up with the same substance, was frozen in a few seconds. But the solidification of the mercury was almost instantly produced by pouring it into a paste made by the addition of a little ether. Frozen mercury is like lead, soft and easily cut. It is ductile, malleable, and insonorous. Just as it is about to melt, it becomes brittle or 'short' and breaks under the point of a knife. These facts may account for the discrepancies of authors on this subject. Frozen mercury sinks readily in liquid mercury.

1227. "At about  $-110^{\circ}$  liquid *sulphurous acid* is frozen, and the ice

\* For engraving and description of Mitchell's modification of Thillorier's apparatus, see Appendix.

sinks in its own liquid, and at  $-130^{\circ}$  alcohol of .798, assumes a viscid and oily appearance, which by increase of cold, is augmented until at  $-146^{\circ}$  it is like melted wax. Alcohol of .820 froze readily. At  $-146^{\circ}$  sulphuric ether is not in the slightest degree altered.

1228. "When a piece of solid carbonic acid is pressed against a living animal surface, it drives off the circulating fluids and produces a ghastly white spot. If held for 15 seconds it raises a blister, and if the application is continued for two minutes a deep white depression with an elevated margin is perceived; the part is killed, and a slough is in time the consequence. We have thus produced both blisters and sloughs, by means nearly as prompt as fire, but much less alarming to my patients."

### Of Oxalic Acid.

1229. Latterly oxalic acid, long known as a product of vegetation, has been found to belong to the compounds of carbon with oxygen; and still more lately mellitic and croconic acid have been added to this class. Yet when the necessity of water to the existence of these acids is taken into view, it appears to me questionable whether they may not be considered as acids with a compound radical, consisting of hydrogen and carbon.

1230. *Preparation.*—Oxalic acid may be obtained from the common sorrel, *Rumex acetosa*, or from the wood sorrel, *Oxalis acetosella*, from which it derives its name. In these plants it exists in the state of binoxalate of potash. It may also be procured by the reaction of one part of sugar with six of nitric acid. The weight of the acid obtained is equal to three-eighths of the materials. Wood, glue, silk, or hair may be substituted for sugar in this process; but when these substances are used, the product is impure. Next to sugar, starch and molasses are probably the best materials. Oxalic acid may be procured also, by digesting shavings of wood in a solution of caustic potash, at a heat considerably above that of boiling water.

1231. *Properties.*—Oxalic acid is a solid, but soluble both in water and alcohol, the resulting solutions being extremely sour. One grain in half a pint of water is sufficient to redden litmus distinctly. It cannot exist uncombined with water or some other base. The atomic composition of this acid would authorize us to consider it as a binary compound of carbonic acid and carbonic oxide. In every atom of oxalic acid in its appropriate crystalline form, there are three atoms of water. When these crystals are exposed to an unusually dry atmosphere, or to a temperature of  $80^{\circ}$ , a partial efflorescence ensues; and if the heat

be raised to  $212^{\circ}$ , they part with two atoms of water which they recover on exposure to the air after cooling. When heated to  $300^{\circ}$ , the acid is decomposed.

1232. Oxalic acid is an energetic poison. The best antidotes for it are magnesia, or the calcareous carbonates in the pulverulent form, especially chalk. When oxalic acid meets with either of these bases, an insoluble and inert oxalate is formed. Hence its employment as a test for lime.

1233. It appears from statements made by Vogel in the *Journale de Pharmacie*, for April, 1836, that the protoxides of iron and copper are precipitated from their union with sulphuric acid by oxalic acid. The oxalate of iron is yellow; the oxalate of copper, blue. Both are insoluble in water.

### *Of Mellitic Acid.*

1234. Mellitic acid is obtained in crystals from a mineral, called the honey-stone, which is a mellitate alumina. It is soluble in water and alcohol, and has a sour taste.

### *Of Croconic Acid.*

1235. Croconic acid may be procured in yellow crystals from the croconate of potash, which is generated in the process for obtaining potassium by means of charcoal. It is inodorous, has an acid and astringent taste, and reddens litmus.

## COMPOUNDS OF CARBON WITH OXYGEN AND CHLORINE.

1236. There are two compounds of carbon with oxygen and chlorine. To one of these, which has been recently discovered, the name of *chloroformic acid* has been given; to the other, that of *chlorocarbonic* or *chloroxy-carbonic acid*. The latter name is preferable; as the other would convey the idea of an acid made solely by the union of chlorine with carbon.

### *Of Chloral.*

1237. When chlorine is passed through alcohol, which consists of hydrogen, oxygen, and carbon, one portion combines with hydrogen, forming chlorohydric acid, while another combines with oxygen and carbon, forming chloral.

1238. Chloral is described as a colourless transparent liquid with a pungent odour. Its specific gravity is 1.502. It boils at  $201^{\circ}$ , and may be distilled unchanged. With water it forms a white crystalline mass, a hydrate.

Chloral consists of nine atoms of carbon, four of oxygen, and six of hydrogen.

### *Of Chloroxycarbonic Acid.*

When one volume of dry chlorine and one volume of carbonic acid are mingled, and exposed to the solar rays, they combine, and into one volume of a colourless acid gas, to which the name of carbonic acid has been given. It is exceedingly offensive to the organs of respiration. It reddens litmus paper, and with water forms a white salt. By contact with water a reciprocal decomposition ensues, and chlorohydric and carbonic acids are produced. It contains one atom of chlorine, and one atom of carbonic oxide.

### *Of the Chlorides of Carbon.*

Chlorine forms four compounds with carbon. The *dichloride* is a crystalline inflammable solid, having a peculiar odour, resembling arsenic. At  $250^{\circ}$  it sublimes in crystals. It is fusible by heat, at a temperature between  $350^{\circ}$  and  $450^{\circ}$ . The dichloride contains one atom of chlorine and two of carbon.

When the liquid, produced by the union of chlorine with olefiant gas, is exposed to the sun, in contact with a sufficient quantity of chlorine, the *sesquichloride of carbon* is produced. It is a transparent, friable, crystalline body, nearly tasteless, and resembles camphor in smell. While exposed to the flame of a spirit lamp, it burns with a red flame, but the combustion ceases as soon as the lamp is extinguished. It melts at  $320^{\circ}$ , and at  $360^{\circ}$  is converted into vapour, which is condensed without decomposition. It is nearly twice as heavy as water. The *sesquichloride of carbon* consists of three atoms of chlorine and two of carbon.

The *protochloride* is obtained by passing the *sesquichloride* in a red-hot porcelain tube. The *sesquichloride* is decomposed into the *protochloride* and chlorine. The *protochloride* is a transparent liquid, with a specific gravity of 1.4875. It is composed of one atom of chlorine and one of carbon.

All the above described chlorides are insoluble in water, acids, and alkalis, but are soluble in oils, alcohol, and ether. When chloral is boiled with potash, a decomposition ensues, and a chloride of carbon is formed in vapour, and may be condensed in a receiver. This chloride is a colourless, transparent liquid, with an odour similar to that of chloric acid; its specific gravity is 1.48. This chloride consists of five atoms of chlorine and four of carbon.

### *Of Bromide of Carbon.*

When bromine is brought in contact with half its weight of peroxide of carbon, heat is evolved, a decomposition ensues, and bromides of carbon are formed. The bromide of carbon is a volatile, colourless, of a sweet taste, and an ethereal odour.

### *Of the Iodides of Carbon.*

The *protiodide* of carbon is a liquid, in properties strongly resembling the bromide of carbon. The *periodide* appears under the form of a solid.

of yellow crystalline scales, which have a sweet taste, a strong aromatic smell resembling that of saffron, and a specific gravity higher than that of water.

*Of Sulphocarbonic Acid, or Bisulphide of Carbon.*

1247. The bisulphide of carbon is obtained by passing the vapour of sulphur over charcoal heated to incandescence in a porcelain tube. It is a transparent, colourless, volatile liquid, possessing an acrid taste, and a peculiar nauseous smell. Its specific gravity is 1.272. It boils at  $105^{\circ}$ , and does not freeze at  $-60^{\circ}$ . At a temperature a little above the boiling point of mercury, it inflames. When the bulb of a spirit thermometer, wrapped in lint imbued with this liquid, is placed within a receiver, and the air withdrawn, the temperature falls to  $-82^{\circ}$ .

1248. This compound unites with almost all the sulpho-bases, forming with them sulpho-salts, and is as well entitled to be treated as an acid, as the analogous compound formed by sulphur with hydrogen.

1249. Dr. Thomson supposes that the solid mass, obtained by washing the nitre out of gunpowder, is probably a solid sulphide of carbon.

COMPOUNDS OF CARBON WITH HYDROGEN.

1250. Carbon and hydrogen are in opposite extremes, as respects their susceptibility of the æriform state. Per se, carbon is probably more difficult of volatilization by heat, than any other substance in nature. Hydrogen, on the other hand, as far as our experience goes, is not susceptible of condensation, even into the non-elastic state of fluidity. There is, however, a powerful affinity between these substances; and hence, when a compound which contains them is subjected to heat, they are made to combine in various proportions, according to the intensity of the ignition, and the influence exercised by the nitrogen, or oxygen, previously in combination with them.

1251. In general, the compounds of carbon with hydrogen are distinguished by inflammability. In the gaseous state they constitute, when ignited, the flame of candles, lamps, gas lights, and culinary fires. They are incapable of supporting life, but are not actively noxious when diluted with the air.

1252. The gaseous compounds of carbon with hydrogen are obtained by the destructive distillation of bituminous coal, wood, oil, tar, and other inflammable substances.

1253. The illuminating power of each of these various kinds of gas, seems to be in proportion to the quantity of carbon contained in a given volume, provided there be an equivalent supply of oxygen; but, otherwise, the excess of carbon renders the flame smoky. Hence the greater bril-



liancy of small flames, or those excited by a current of air, as in the Argand lamp. The same flame which in common air is unpleasantly fuliginous, transferred to oxygen gas, displays a perfect brilliancy.

1254. The known compounds of carbon with hydrogen are numerous and complicated; and yet it is probable that many exist in nature, or may be produced by art, with which we are at present unacquainted.

1255. We have had occasion to state, (1153,) that where bodies have, in the same volume, the same number of atoms of each of their ingredients, and yet differ in their properties, they are said to be *isomeric*, from *ισος* equal, *μερος* part. Compounds, in which the constituents are in the same ratio, but in which the resulting volumes exist in different degrees of condensation, are said to be *polymeric* with respect to each other, from *πολυς* many, *μερος* part. The last term is applied to a class of the compounds of carbon with hydrogen, in all of which these elements exist in the same ratio of atom for atom; yet from some difference in the mode of aggregation, or, as I believe, in the extent and modes of their association with heat, light, and electricity, their degree of condensation when in the æriform state, and their properties in other respects are quite different.

1256. We have then two groups of the carburets of hydrogen, in one of which diversity of properties is attended by a corresponding diversity in the ratio of the carbon to the hydrogen; while in the other this ratio is uniform, although the properties and resulting volumes in the æriform state, differ. In the first group, there are four compounds.

1257.—1. *Light carburetted hydrogen*, or *fire damp*, consisting of two volumes or atoms of hydrogen, with one volume or atom of carbon.

1258.—2. The compound, in all the varieties of which there are as many atoms of one element as of the other, and for which Dr. Thomson proposes the name of *carbohydrogen* as a generic appellation.

1259.—3. *Bycarburet of hydrogen*, in which six atoms of carbon are united with three of hydrogen.

1260.—4. *Naphthaline*, in which ten atoms of carbon are combined with four atoms of hydrogen.

1261. The second group, which is subordinate to the first, being formed in fact by the ramifications of carbohydrogen, comprises, according to Dr. Thomson, several varieties, which he designates and describes as follows:—

1262.—1st. *Protocarbohydrogen*, consisting of a volume of carbon and a volume of hydrogen, condensed into one volume. This variety, now called *mytheline*, has been lately isolated by Dumas and Peligot, by distilling one part of pyroxylic spirit, obtained by the distillation of wood, with two parts of chlorohydric acid, and three of sulphuric acid; when an ethereal chlorohydrate of mytheline results. Subjected to a red heat, this ethereal compound is resolved into chlorohydric acid gas, and mytheline in the gaseous form. Pyroxylic spirit is considered as a bihydrate of mytheline, being procured from crude pyroligneous acid by distillation. It bears the same relation to mytheline that alcohol does to etherine. (1267.)

1263.—2d. *Deutocarbohydrogen*, or *olefant gas*, consisting of two volumes of carbon and two of hydrogen, condensed into one volume.

1264.—3d. *Tritocarbohydrogen*, consisting of three volumes of carbon

and three of hydrogen, condensed into one volume. This is by Dr. Thomson considered as constituting the gas evolved from oil, which was by Dalton called super-olefiant gas.

1265.—4th. *Tetartocarbohydrogen*, consisting of four volumes of carbon, and four volumes of hydrogen, condensed into one volume.

1266.—5th. *Hexacarbohydrogen*, containing, according to Thomson, six volumes of each element, condensed into one volume.

1267. *Of Etherine*.—Besides these compounds, it has been inferred, by many chemists, that there is a liquid, or solid compound, formed of four volumes or atoms of carbon, and four volumes or atoms of hydrogen, condensed into one volume or atom. This has been called etherine, under the idea that it is the common base of all the ethers, forming common ether by uniting with one volume of aqueous vapour, alcohol, by uniting with two such volumes, and the various ethers, by uniting with acids, or the other ingredients, after which they are severally named. Etherine would of course be isomeric with the tetartocarbohydrogen of Dr. Thomson. (1265.)

### *Of Light Carburetted Hydrogen, or Fire Damp.*

1268. The substance distinguished by these names has been dignified by a variety of appellations, among which are heavy inflammable air, carburetted hydrogen, and bihydroguret of carbon. Dr. Thomson has, in some instances, used the monosyllable *di* to indicate proportions the inverse of those indicated by the monosyllable *bi*. Thus, bichloride of carbon would signify two atoms of chlorine and one of carbon, while dichloride conveys the idea of two atoms of carbon and one of chlorine. Consistently, then, I think, Dr. Thomson should have called this gas, a *dicarburet of hydrogen*; as the proportions of its constituents are the inverse of those in the bicarburet. This gas has long been known to miners of bituminous coal, under the name of fire damp, as one of their greatest enemies. It is liberated copiously from cavities in the coal, in which, no doubt, in many instances, it has been pent for ages. It is also evolved from the mud of stagnant waters, and is occasionally emitted from fissures in the earth. There is no good mode of forming it artificially. It is a colourless gas, of course irrespirable but having more than a negative influence in destroying life. Its specific gravity is 0.5593.

### *Of the Safety Lamp.*

1269. In the account above given of dicarburet of hydrogen, it was mentioned that it was in mines a source of injury. When existing in the air beyond a certain proportion, it explodes on coming into contact with the flame of a lamp or candle. Hence, as artificial light is necessary in mines inaccessible to the light of day, the use of candles or lamps, in the ordinary way, has been frequently destructive to the workmen. It had, of course, been the cause of great misery to them, and of embarrassment to the proprietors of the mines.

1270. In order to avoid the risk attending the use of lamps or candles in mining, "steel mill" had been resorted to, in which the rapid revolution of a steel wheel against a flint, was made to produce a succession of sparks, and of course a feeble light. I believe that the security afforded by this invention was imperfect, and the light insufficient. Explosions have been more frequent in the English mines of late years probably in consequence of the greater extent and depth to which they are excavated. While under the painful impression made by some recent catastrophes of this nature in which many miners had been killed or mutilated, Sir H. Davy exerted himself to discover the means of sustaining flame safely within explosive gaseous mixtures. He soon ascertained that his object might be effected by enclosing the flame in a cage of wire gauze, so as to allow of no communication with the surrounding medium, which does not take place through the meshes of the gauze. (Owing to t

ing power of the wire, the mixture cannot pass through the meshes in a state of bustion. Of course the inflammation is confined within the wire gauze.

71. The method in which I illustrate the operation of the safety lamp, may be y comprehended from the following figure. The lamp is seen within a large



glass cylinder upon a stool. The cylinder is closely covered by a lid, which will not permit the passage of air between it and the cylinder, and which is so light as to be easily blown off. Excepting the cage alluded to above, the safety lamp does not differ materially from those which are ordinarily used. The upper surface of the receptacle for the oil, forms the bottom of the cage, which is so closely fitted to it, and so well closed every where, as to allow air to have access to the flame only through the meshes of the wire gauze. The cage is enclosed within three iron rods, surmounted by a cap, to which a ring for holding the lamp is attached, as seen in the figure.

1272. If, while the lamp is burning, as represented in the figure, hydrogen, either pure or carburated, be allowed, by means of the pipe, to enter the glass cylinder, so as to form with the air in it an explosive mixture, there will nevertheless be no explosion. It will be found that as the quantity of inflammable gas increases, the flame of the lamp enlarges, until it reaches the wire gauze; where it burns more or less actively, accordingly as the supply of atmospheric air is greater or less. It will, under these circumstances, often appear as if the combustion had ceased; but on increasing the

portion of atmospheric air, the flame will gradually contract, and finally settle the wick, which will burn as at first when the supply of hydrogen ceases.

73. If the cage be removed from the lamp, and the experiment repeated in all respects as at first, an explosion will ensue, as soon as a sufficient quantity of oxygen is allowed to enter the cylinder.

### *Deutocarbohydrogen, or Olefiant Gas, called also Carburated Hydrogen, and Hydroguret of Carbon.*

1274. This gas received its name in consequence of its being condensed with chlorine into a liquid, having an oily consistency, although otherwise unlike an oil. It was discovered in the year 1796. It may be obtained by subjecting a mixture of five parts of sulphuric acid with one of alcohol to heat in a glass retort. It is invisible, and possesses, like other gases, the mechanical properties of atmospheric air. Its specific gravity is 0.9808. When drawn into the lungs it produces asphyxia. It burns with great splendour, and detonates with oxygen with such violence, that without some precautions it is dangerous to

analyze it by the usual processes. I have had several eudiometers broken by it, but have latterly avoided that accident, by exploding the mixture in a rarefied state, into which it is easily brought in some of the instruments which I employ.

1275. The analysis may be performed in the volume-scope for analyzing the air by means of hydrogen, with a degree of accuracy sufficient for the purpose of illustration. Four volumes of oxygen should be added to one of the gas. The ignition being effected as already described in the case of pure hydrogen, it will be seen that the five volumes are reduced to less than three, and that by the introduction of lime-water, these three may be reduced to one residual volume of oxygen. The reason why the residual gas is less than three volumes, is, that the carbonic acid formed is partially absorbed by the water. As the gas contains in one volume, two volumes of hydrogen, and two of carbon vapour, it will, for the latter, require two volumes; for the former, one volume of oxygen. Of course the hydrogen, and the oxygen which combine with it, will be condensed; so that after the explosion, unless so far as absorbed by the water, two volumes of carbonic acid will remain mingled with the one volume of oxygen in excess.

*Of certain Gaseous Compounds formed by igniting the Gaseous Elements of Water, while containing Olefiant Gas, or the Vapour of Ethers, or Essential Oils.*

1276. I observed some years ago, that when olefiant gas is inflamed with an inadequate supply of oxygen, carbon is deposited, so copiously as to render the glass receiver of the eudiometer impervious to light, while the resulting gas occupies double the space of the mixture before explosion. Of this I conceive I have discovered the explanation. By a great number of experiments, performed with the aid of my barometer-gauge eudiometer, I have ascertained that if during the explosion of the gaseous elements of water any gaseous or volatile inflammable matter be present, instead of condensing there will be a permanent gas formed by the union of the nascent water with the inflammable matter. Thus two volumes of oxygen, with four of hydrogen, and one of olefiant gas, give six volumes of permanent gas, which burns and smells like light carburetted hydrogen. The same quantity of the pure hydrogen and oxygen, with half a volume of hydric ether, gives on the average, the same residue. One volume of the new hyponitrous ether, under like circumstances, produced five volumes of gas.

1277. An analogous product is obtained when the same aqueous elements are inflamed in the presence of an essential oil. With oil of turpentine a gas was obtained, weighing, per hundred cubic inches,  $16\frac{2}{10}$  grs., which is nearly the gravity of light carburetted hydrogen. The gas obtained from olefiant gas, or from ether, weighed on the average, per the

same bulk,  $13\frac{5}{10}$  grs. The olefiant gas which I used, weighed per hundred cubic inches, only  $30\frac{5}{10}$  grs. Of course, if, per se, expanded into six volumes, it could have weighed only one-sixth of that weight, or little over *ve grains* per hundred cubic inches. There can, therefore, be no doubt that the gas obtained by the means in question is chiefly constituted of water, or of its elements, in the proportion in which they exist in that liquid. See table, page 189, for steam.

1278. The gas created in either of the modes abovementioned does not contain carbonic acid, and when generated from olefiant gas, appears by analysis to yield the same quantity of carbon and hydrogen as that gas affords before expansion.

1279. These facts point out a source of error in experiments, for analyzing gaseous mixtures by ignition with oxygen or hydrogen, in which the consequent condensation is appealed to as a basis for an estimate. It appears that the resulting water may form new products with certain volatilizable substances which may be present.

1280. The gas obtained by passing the vapour of alcohol through an ignited porcelain tube, is confounded generally with that which results from the reaction of sulphuric acid with alcohol, as above described, (1273,) but equal volumes of the gaseous products obtained, the two processes being analyzed, I found that procured by ignition to have only condensed half as much oxygen as the other. From the facts above stated, that the presence of water causes a union between its elements, and those of the carbon and hydrogen of carburets, whether in the form of vapour or gas, it may be inferred that the products of the decomposition of alcohol must vary accordingly as it may be more or less anhydrous. The alcohol which I employed was of the specific gravity nearly of 840°: were absolute alcohol subjected to the process in question, a gas containing a larger proportion of carbon might be obtained. (619, 1252.)

### *Experimental Illustrations.*

1281. Cork, cotton-seed, caoutchouc, and nuts, introduced in small quantities into a gun-barrel, of which the butt-end has been heated to a bright red-heat. Brilliant jet of flame proceeds from the touch-hole. Inflammation of the gas extricated by distillation from oil or bituminous coal, also of olefiant gas. Olefiant gas, mixed with oxygen gas, and exploded in a sliding-rod eudiometer. Residue renders lime-water milky.

#### *Of Gas Lighting.*

1282. The gaseous compounds of carbon and hydrogen have been much applied to the purpose of illumination.

1283. The gas, for this purpose, is obtained by the destructive distillation of bituminous coal, oil, or resinous substances, and is received in gasometers, whence it is distributed through pipes to the burners. (617, 1252.)



1284. One of the greatest obstacles to the general employment of gas lights as a substitute for candles and lamps, is the necessity of pipes leading from gasometers to all situations where the light is wanted. The condensation of the gas into strong metallic receivers, has been resorted to in order to obviate this difficulty. This process may be illustrated by means of the apparatus described for the impregnation of water with carbonic acid, being modified as represented in the adjoining cut.

1285. It is only necessary to exchange the communication with the self-regulating reservoir of carbonic acid gas, for a similar communication with a reservoir of olefiant gas; and the copper vessel being first exhausted of air, to condense the gas into it. The siphon used for the efflux of the impregnated water, is replaced by a cock and tube, the latter terminating in a capillary perforation. Through this, the gas may be allowed to escape in a proper quantity to produce a gas light when inflamed. It has, however, always appeared to me, that the expense of condensing the gas, and of procuring and transporting the receiver, would render this method of affording light disadvantageous.

1286. Latterly, the loss of gaseous matter, by condensation, has been found so great as to render the process unprofitable.

### *Of some Varieties of Carbohydrogen, and of the Bicarburet of Hydrogen.*

1287. Tetartocarbohydrogen, hexacarbohydrogen, and bicarburet of hydrogen were all obtained by Mr. Faraday from the liquid which is deposited from oil gas, when condensed into vessels under great pressure for the purposes of illumination.

1288. On subjecting the matter, deposited as above described, to a very gentle heat, *tetartocarbohydrogen* is separated in the form of a transparent, colourless, inflammable gas, with a specific gravity of 1.9444. When cooled to zero, it condenses into a transparent colourless liquid of the specific gravity of 0.627, being the lightest liquid known.

1289. When the liquid remaining after the extrication of the tetartocarbohydrogen is heated, vapour is evolved, and the boiling point continually rises until the temperature of  $176^{\circ}$  is attained. Between this temperature and  $190^{\circ}$ , a large portion distils in the form of a liquid. When this liquid is cooled to zero, it separates into two compounds, one of which becomes solid, while the other continues liquid. The liquid is the compound which Dr. Thomson calls *hexacarbohydrogen*, though its composition does not appear to have been well ascertained. It is inflammable, soluble in alcohol, and boils at  $176^{\circ}$ . The solid compound is the *bicarburet of hydrogen*. It is at ordinary temperatures a colourless, transparent, volatile liquid, which boils at  $186^{\circ}$ , and has a specific gravity of 0.85. At  $32^{\circ}$  it crystallizes, and, when cooled to zero, acquires a consistency like that of loaf sugar.

### *Of Naphthaline.*

1290. Naphthaline is obtained by subjecting to distillation the tar which is formed during the decomposition of bituminous coal. The first products are ammonia water, and the liquid called coal naphtha; but towards the close of the process, naphthaline is obtained.

290. Naphthal white crystalline substance, with an aromatic odour, and a pungent disagreeable taste.

291. There are other compounds of carbon and hydrogen,—native bitumens for instance, and oil of turpentine. The almost endless variety of essential oils derived from vegetables, consist either wholly or principally of carbon and hydrogen. Of some of these I shall hereafter briefly treat; notice them all would be inconsistent with the limits prescribed to this book.

*Of the Compounds formed by Carbon with Chlorine and Hydrogen.*

292. It has already been stated that olefiant gas received its name in consequence of its being condensable with chlorine into a liquid of an oily consistency. To this liquid the name of chloric ether has been improperly given, as it indicates a dependency on chloric acid for its constitution or generation, contrary to the fact. As it consists of two atoms of chlorine and one of etherine, a more appropriate name would be *bichlorine ether*.

293. Bichlorine ether is limpid and colourless like water, has a pleasant odour, and an agreeable sweet taste.

294. Chlorine combines with several other of the polymeric varieties of hydrogen, forming with them compounds of different properties. It produces two compounds by combining with the bicarburet of hydrogen; one solid, the other liquid.

COMPOUND OF CARBON WITH NITROGEN.

*Of Bicarburet of Nitrogen, or Cyanogen.*

1295. Cyanogen ranks next to iodine among electro-negative bodies. It is included among the halogen bodies by Berzelius, and in the basacigen class by me. (625, 634.) In forming a compound, I have deferred treating of it until now.

1296. *Preparation.*—Cyanogen is obtained by subjecting red and dry bichyanide of mercury to a low red-heat in a retort or coated glass retort or tube, and receiving the product over mercury.

1297. *Properties.*—Cyanogen is a colourless, transparent, irrespirable gas, which painfully affects the nose and eyes, and has a strong and peculiar odour. Under a pressure of four atmospheres, it becomes a colourless liquid, lighter than water. It may likewise be liquefied, or even solidified by cold. It is characterized by burning with a beautiful violet flame. It is decomposed by the electric spark, or by an incandescent iron, into its constituents, carbon and nitrogen. Alcohol dissolves twenty-three times, and water four and a half times its volume of cyanogen. In the course of a few days the solutions become discoloured, and a brown matter is deposited. The deposition from al-

cohol has been found to contain carbon and nitrogen. After obtaining cyanogen from the bichyanide of mercury, a black residuum is found in the retort, which has been conceived to consist of carbon with a lesser proportion of nitrogen than exists in cyanogen; but of late, this residuum, and the deposition from alcohol, have been supposed to be isomeric with cyanogen.

1298. When ignited with two volumes of oxygen, a volume of cyanogen is converted into two volumes of carbonic acid and one of nitrogen, without condensation. Of course, as each volume of carbonic acid requires a volume of carbon vapour, there must exist two such volumes in one of cyanogen. Hence, as in the case of carbon and nitrogen each volume represents an atom, cyanogen consists of

$$\begin{array}{rcl}
 \text{two atoms of carbon} & = & 12 \\
 \text{and one of nitrogen} & = & 14 \\
 & \text{---} & \\
 \text{and its equivalent is} & & 26
 \end{array}$$

*Of the Nomenclature of the Compounds of Cyanogen.*

1299. When Prussian blue is digested with a solution of potash, and the resulting solution is filtered while hot, yellow crystals are deposited by refrigeration, called ferropotassiate or ferrocyanate of potash, under the idea that they consist of an acid composed of iron, cyanogen, and hydrogen, in union with the oxide of potassium. Berzelius considers these yellow crystals as a double salt, formed by a "*cyanure*" of iron, and a "*cyanure*" of potassium. The name of this double salt, agreeably to his nomenclature, is "*cyanure ferroso-potassique*." There is another compound containing the same elements, in which the proportion of cyanogen to that in the first mentioned compound, is as  $1\frac{1}{2}$  to 1, and for which his name is "*cyanure ferrico-potassique*."

1300. The existence of these combinations constitutes one instance among many, in which, according to Berzelius, two compounds, each having the same halogen body as an ingredient, form by their union a double salt.

1301. Agreeably to his system, we have double "*chlorures*," "*bromures*," "*fluorures*," and "*iodures*," as well as double "*cyanures*."

1302. Some years ago, Bonsdorf, a skilful and sagacious German chemist, assailed this classification of Berzelius, by showing that some of the "*chlorures*" of the double salts exercised an alkaline, others an acid reaction, with vegetable colouring matter; and that consequently the double "*chlorures*," so called by Berzelius, were really simple salts, in which one chlorure acted the part of an acid, the other of a base. Merely on contemplating the facts of the case, as stated by Berzelius, without having any knowledge of Bonsdorf's experiments and conclusions, the conviction arose in my mind that the double haloid salts, of that great chemist, should be considered as compounded of acids and bases. I cannot conceive wherefore Bonsdorf thought it necessary to show that the ingredients of a double chlorure should be capable of reacting with vegetable colouring matter, as if



of them were acid, the other a base, in order to prove their pretensions severally, to acidity and basidity. (629.) It appears to me, that, cepting in the case of the alkalies and alkaline earths, those properties have not been deemed essential to oxacids and oxibases, and that of course they ought not to be required in acids or bases formed by any other of the sacigen class. Agreeably to the definition of acids and bases, on which the basacigen classification is founded, (630 to 632,) the "*cyanure*" of iron is more electro-negative as contrasted with the "*cyanure*" of potassium, the former must be deemed a cyanobase, the latter a cyanacid.

1303. It has been mentioned by British and French chemists the termination in *ide* was made to indicate a compound formed by a supporter in combustion with a combustible or *ure*, while the termination in *uret* was employed to designate a compound formed of two radicals. The difference in the practice of the two schools arose from the extension of the class of supporters by the chemists of Great Britain to the simple hydrogen elements of Berzelius, whereas, according to those of France, oxygen is the only supporter, all the other elements being combustibles or radicals. (685, &c.) Hence, according to the latter, only the compounds formed with oxygen have been distinguished by the termination in *ide* as in oxide; while, according to the former, in addition to those formed with oxygen, we have such as are formed by chlorine, bromine, iodine, and fluorine, distinguished by the termination in *ide*, as has been already, to a certain extent, explained. (685.)

1304. By Berzelius the termination in *ide* is only resorted to where the radical is an electro-negative body; or, in other words, a body of which the oxides go to the positive pole. When the radical is one of those bodies which, when oxydized, go to the negative pole, the termination in *ure* is resorted to. I object to this complicated nomenclature, as founded on the error of not allowing those characteristics of acids and bases which have been acted upon by chemists in general, and by Berzelius himself in the case of oxacids and oxibases, to extend to the binary compounds formed by the bodies of the halogen class.

1305. I consider the yellow salt in question, as consisting of a cyanacid containing an atom of cyanogen and an atom of iron, and which I would call *cyanoferrous acid*, united to a cyanobase of potassium, consisting of an atom of cyanogen, and one atom of potassium, and forming a *cyanoferrite of potassium*. The double salt, consisting of the same elements, containing both in the acid and base, half an atom more of cyanogen, would, by analogy with the oxacids, have its acid distinguished by the name of *cyanoferric acid*, and should itself be called *cyanoferrate of potassium*.

#### *Of Cyanic, Cyanuric, and Fulminic Acids.*

1306. An atom of cyanogen, combined with an atom of oxygen, forms *cyanic acid*, which may be obtained in union with potash, by igniting *oxide* of manganese with ferropotassiate of potash, or cyanoferrite of potassium; being the salt alluded to above, as consisting of cyanogen, iron, and potassium. The cyanogen and potassium are converted, by the excess of oxygen in the manganese, into cyanic acid and potash, which unite, forming a cyanate of potash. Cyanic acid cannot, however, be obtained from the cyanates, in consequence of its extreme susceptibility of decomposition.

1307. A crystalline substance may be procured from human urine, which

is known by the name of urea. It consists of carbon, nitrogen, oxygen, and hydrogen, in the proportion to form one atom of cyanic acid, one atom of ammonia, and one atom of water. When urea is subjected to heat, ammonia escapes, and an acid remains, which was supposed to consist of one atom of cyanogen, and two atoms of oxygen. But it has been recently ascertained by Wohler and Liebig, that it consists of the elements of cyanic acid, chemically united to the elements of water; an atom of hydrogen, and an additional atom of oxygen, entering into its composition, not as water, but as essential constituents. Under these impressions, a new name, *cyanuric*, was given to it. This acid is solid, fixed, inodorous, and nearly tasteless. By combining with two atoms of water, as water of crystallization, it becomes capable of forming large crystals.

1308. When anhydrous cyanuric acid is exposed, in a glass retort, to a low red-heat, the extricated vapours being collected in a receiver refrigerated by a freezing mixture, hydrous cyanic acid is obtained. This acid and cyanuric acid consist of the same elements in the same proportion, but possess different properties and atomic weights. Hydrous cyanic acid is a colourless, volatile liquid, possessing a penetrating odour resembling that of acetic acid. It vesicates the skin when applied to it, exciting intense pain. Its vapour reddens litmus paper, is inflammable, and so pungent as to produce tears, and cause severe pain in the hands. Cyanuric acid is comparatively inert in these respects, but is far less susceptible of decomposition; as it is not decomposed by solution in boiling nitric or sulphuric acid, while hydrous cyanic acid is decomposed by the addition of water.

1309. Hydrous cyanic acid, at the ordinary temperature of the air, spontaneously undergoes an explosive decomposition, attended by an evolution of heat, and is converted into a solid mass of dazzling whiteness. This mass consists of a variety of cyanuric acid, which differs from that above described, in being insoluble in water or nitric acid, and in being decomposed by sulphuric acid. It is, therefore, to be considered as presenting a case of isomerism. (1153).

1310. It is remarkable that, although cyanuric acid consists of the same elements in the same proportion as hydrous cyanic acid, it carries the hydrogen and oxygen which exist in it in the proportion to form water, into every combination which it forms; while the hydrous cyanic acid, in combining with bases, separates from the water, which must be considered, when in union with this acid, as acting as a base.

1311. To bodies which, although they contain the same elements in the same ratio, yet hold them differently associated, so that in reacting with other agents, they are resolved into, or form compounds differing in composition, the term *metameric* has been applied. Thus hydrous cyanic, and cyanuric acid are said to be metameric with regard to each other.

1312. Another compound of cyanogen with oxygen exists in the fulminating mercury of Howard, and the analogous fulminating silver of Descotils. Liebig ascertained these compounds to contain an acid common to both, which he called *fulminic acid*, but which, agreeably to the analysis made by him and Gay Lussac, was identified in composition with cyanic acid. Yet, as the latter would not produce fulminating compounds, and differed in its other properties, these acids have been considered as affording another instance of isomerism. Mr. Edmund Davy, however, alleges the existence of hydrogen in fulminic acid, and likewise that the nitrogen exists in excess, beyond the proportion appropriate to cyanogen.

1313. Fulminic acid is a colourless, transparent, volatile liquid, which

s litmus, and produces a taste at first sweet, but afterwards astringent and disagreeable. Its fumes have a pungent and disagreeable odour, and give a headach when incautiously inhaled.

4. Besides these acids, M. Liebig has recently discovered another, which is polymeric with regard to cyanuric acid; as it consists of the same elements in the same ratio, though twice as much of each enters into the constitution of an atom.

#### *Of the Chlorides, Bromides, and Iodides of Cyanogen.*

5. Chlorine forms two compounds with cyanogen, a protochloride and perchloride. The *protochloride* is a colourless, fetid gas, which may be liquefied, and even solidified by cold. In common with several other kinds of cyanogen, it possesses, even when gaseous, the singular property of producing pain by contact with the skin. The *perchloride* is a crystalline substance, with an odour resembling that of mice.

6. Bromine and iodine both form with cyanogen, crystalline compounds. The chlorides and bromides of cyanogen are energetic poisons.

#### *Of Sulphocyanogen.*

7. It has been stated that the yellow salt, usually known as ferrocyanide of potash, is by Berzelius considered, when free from water, as a compound of cyanogen, iron, and potassium; also that I consider it as a cyanide of the cyanobase of potassium. When this salt, desiccated to dryness and finely pulverized, is mingled with flowers of sulphur, and heated to a red-heat in a porcelain crucible, the iron is displaced; the sulphur and cyanogen uniting, form a compound called sulphocyanogen, and uniting with the potassium, constitutes a sulphocyanide. (1802.)

8. Sulphocyanogen has been isolated by passing chlorine through a solution of sulphocyanide of potassium, or by subjecting that compound to heat. Sulphocyanogen has some pretensions to be classed with the acids, and of course with the basigen bodies.

9. The intense blood-red colour which it produces with iron, is the striking property of sulphocyanogen, and has led to the impression that the sulphocyanide of iron may be the colouring matter of the blood.

10. Sulphocyanogen is solid, insoluble in water or alcohol, and may, in the anhydrous state, be sublimed without change. It is composed of one atom of cyanogen, and two atoms of sulphur.

11. Dr. Thomson states that another compound of sulphur and cyanogen exists, containing one atom of sulphur and two atoms of cyanogen. This compound may be obtained in transparent colourless crystals. It is solid, possesses a strong smell, and is soluble in water. When applied to the tongue, even in a minute quantity, it produces intense pain; and the affected remains red and painful for some time.

#### *Of Sulphocyanhydric Acid.*

12. This acid may be obtained from a solution of the sulphocyanide of potassium, by the addition of phosphoric acid. Water is decomposed, the cyanogen unites with the potassium, forming potash, with which the phosphoric acid combines, and the hydrogen with the sulphocyanogen, forming sulphocyanhydric acid, which may be separated by distillation. This acid is colourless, has an acid taste, and powerful odour. It becomes

solid at  $14^{\circ}$ , and boils at  $216^{\circ}$ . It is composed of one atom of sulphocyanogen, and one atom of hydrogen.

### *Of Cyanhydric or Prussic Acid.*

1323. One atom of cyanogen, equivalent 26, with one atom of hydrogen, equivalent 1, forms one atom of cyanhydric acid, equivalent 27.

1324. This acid has been detected in water distilled from bitter almonds and from laurel leaves, also, from peach leaves or blossoms. Between the odour of these, and that of the acid when dilute, it would be difficult to discriminate.

1325. Laurel water has long been known as a poison. Water distilled from peach leaves has been used to impart an agreeable flavour to food. Some peach leaf water, prepared by Mr. Wetherill, gave indications of cyanhydric acid, by producing a blue colour with a solution of iron.

1326. There have been instances in which noyau, a cordial made from the kernels of bitter almonds, has proved poisonous from the presence of cyanhydric acid.

1327. There is a salt consisting of two atoms of cyanogen and one of mercury, called bicyanide of mercury. When this salt is subjected to the action of chlorohydric acid, the chlorine forms a chloride with the mercury, while the hydrogen forms cyanhydric acid with the cyanogen.

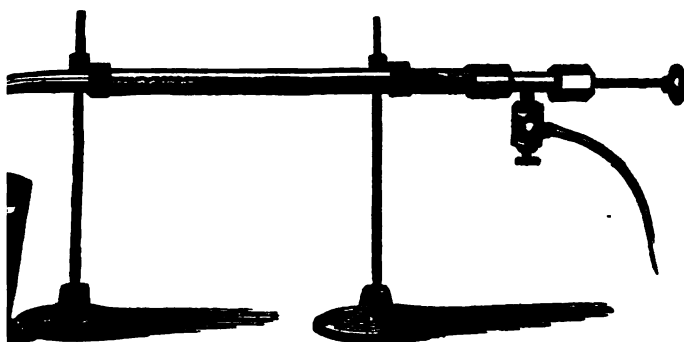
1328. It may be more conveniently obtained by impregnating with sulphydric acid, a solution containing sixty grains of bicyanide of mercury for every ounce of water. The hydrogen unites with the cyanogen, while the sulphur precipitates with the metal. Any excess of the sulphydric acid is easily removed by the carbonate of lead. The apparatus for impregnation with sulphydric acid, has been described already. (797-8.)

1329. The acid may be procured in its most concentrated form, by exposing the bicyanide in crystals, in a tube, to sulphydric acid gas, and employing a receiver, surrounded by salt and snow, to condense the vapour evolved.

1330. In performing this process, I found great difficulty to arise from the inability of the operator to regulate the quantity of gas introduced into the tube, so that, on the one hand, there might be no absorption of atmospheric air, and, on the other, no excess of the gas escaping, and

quently causing a loss of materials, and annoyance to bystanders. This difficulty is in great measure relieved, by means of the apparatus of which an engraving description is subjoined.

*Apparatus for the Evolution of Cyanhydric or Prussic Acid.*



Let a tube, three-fourths of an inch in bore and about two feet in length, be bent at right angles, at about six inches distance from one end. Let the shorter end be drawn out into a tapering form, with a bore not exceeding a tenth of an inch in diameter. Upon the larger orifice let a brass band be cemented, in which a screw has been cut, so that a stuffing-box, furnished with a corresponding screw, may be easily fastened air-tight to the band, or removed when desirable. Through the stuffing-box an iron rod passes, flattened like an oar at the end, which is used to stir the contents of the tube when the stuffing-box is in its place. There must likewise be a communication in the band communicating with the cavity of the tube, and furnished with a galloway screw. The main body of the tube is to be situated nearly horizontal, a little inclined towards the curvature, so that the tapering extremity may nearly perpendicularly into a tall narrow phial, surrounded by a freezing mixture.

The horizontal portion of the tube near the bend should likewise be regulated. The apparatus being thus arranged, introduce a sufficient quantity of quicksilver into the tube, and close it by inserting the stuffing-box. In the next place, by means of the galloway screw, make a communication between the cavity of the tube, and a self-regulating reservoir of sulphydric gas must be allowed to pass into the tube very slowly, and meanwhile, the rod, the bichyanide is to be stirred. Before long a portion of the cyanhydric acid will be seen in the narrow part of the tube. This serves to regulate the evolution of the sulphydric acid, since, when the quantity passing into the tube is moderate, the liquid will rise in the tube; when too great, it will be expelled. By these means, after a little while, all the bichyanide will be decomposed, and a corresponding quantity of acid collected in the refrigerated phial.

Since this figure was engraved, I have found it preferable to have a phial with a bottom tapering to a point, so that the quantity of acid, however minute, is apparent; and it is sooner rendered competent to act as an index of the progress of the process; so as to regulate the quantity of gas to be allowed to enter the tube. It has also been found advantageous to mix the bichyanide intimately with its bulk of glass, powdered to the consistency of coarse sand.

#### *New Process for Liquid Cyanhydric Acid.*

The following process for procuring prussic acid, is recommended by Mr. Everitt.\*

For every 212 grains of ferroproussiate of potash (cyanoferrite of iron) in 2 ounces of water introduced into a retort, add as much sul-

\* London and Edinburg Philosophical Magazine, vol. 6, p. 100.

phuric acid as may be equivalent to 120 grains of the anhydrous acid; and distilling the mixture, let the vapour pass into a pint of refrigerated water, holding 255 grains of nitrate of silver. The resulting precipitate being washed and dried, should constitute nearly 201 grains of mercurial cyanide. Of this let 40 grains be introduced into 7 fluid ounces, and 20 minims of water; and add 40 minims of chlorohydric acid, of specific gravity of 1.125. The whole being well secured in a stoppered bottle, and agitated repeatedly, should be allowed to rest until the resulting chloride of silver subsides. In the solution thus obtained, when carefully decanted, there will be one grain of prussic acid (more properly called cyanhydric acid,) for every fluid ounce of water.

1335. Should there be a little excess of chlorohydric acid, agreeably to Professor Everitt's observation, confirmed by those of others, it will tend rather to preserve, than to decompose the acid.

1336. *Properties of Cyanhydric Acid.*—This acid is a colourless liquid, which emits a powerful odour, resembling that of peach blossoms. When perfectly free from water, it is far more volatile than ether, as it boils at 79° F., and evaporates so rapidly, that one portion becomes frozen by the loss of the caloric which the other absorbs in passing into the æriform state. Its specific gravity is 0.7058, being nearly the same as that of sulphuric ether.

1337. Anhydrous cyanhydric acid is sometimes decomposed in a few hours, especially if not protected from the light, and can never be preserved longer than a fortnight. Either when in the state of a liquid, or vapour, this acid is probably the most active poison known. The application of a few drops to the arm of a man has produced death, and its fumes are equally deleterious when inspired. As when free from water, this acid boils at 79°, nearly 20° below the temperature of the blood, it must be converted into vapour too soon to produce its full effect. From a cavity like the ear, the pure acid must be ejected in vapour immediately. I am, therefore, under the impression that it is less effectual as a poison when anhydrous, than when combined with a minute proportion of water.

1338. Upon one occasion, touching the ear of a rat confined in a glass jar with a drop of the anhydrous acid, the animal, being obliged to breathe the vapour, died instantaneously with a slight sneezing. Yet upon another occasion nearly half a drachm was injected into the ear of a large dog, without causing death; a like quantity, subsequently injected into his nose, proved fatal. The acid employed was so pure as to freeze by its own evaporation.

1339. The best antidotes for this poison are chlorine or ammonia, in dilute aqueous solution, especially chlorine.

1340. Cyanhydric acid is sometimes employed in medicine, though in very small doses, and in a very diluted state.

1341. It has been proposed to detect cyanhydric acid, in cases in which it may have been employed in poisoning, by subjecting the stomach and its contents to distillation with water, and testing the liquid product by copper or iron.

1342. I should place much reliance on the characteristic smell of the acid, which is that of peach blossoms, and which may be perceived, not only from the presence of the acid, but likewise from that of any of the cyanides, if subjected to the action of chlorohydric acid.

#### *Experimental Illustrations.*

1343. The processes for the production both of the aqueous and anhydrous cyanhydric acid, exhibited; also, the congelation of the latter by the cold arising from its own evaporation.



### SECTION V.

#### OF BORON.

1344. *Preparation.*—By the addition of sulphuric acid to a saturated solution of biborate of soda (borax) in water, shining crystalline plates are precipitated, consisting of silicic acid. From these crystals boron may be obtained, either by the action of a powerful Voltaic series, or by not vitrifying them, then finely pulverizing the resulting mass, and afterwards heating the acid thus prepared in contact with potassium.

1345. Boron may be obtained by means of the apparatus employed for the evolution of silicon, (1355, &c. 357, &c.) substituting fluoboric acid gas for fluosilicic acid gas.

1346. *Properties.*—Boron is of a dark olive colour, tasteless, inodorous, a non-conductor of electricity, and insoluble either in alcohol, ether, or the oils. Its atomic weight

is 11. It is susceptible neither of fusion nor volatilization. When heated in the air to  $600^{\circ}\text{F}$ , it takes fire, and, by uniting with oxygen, generates boric acid. Nevertheless only a portion of the boron is oxydized, the remainder being protected by a crust of fused boric acid. If this crust be removed by water, the boron will be found to have undergone a change similar to that produced in charcoal by an intensely high temperature. It is rendered harder, more difficult to ignite, and so much denser, that, although its specific gravity was before only 1.83, it now sinks rapidly in sulphuric acid of the specific gravity of 1.844. Before it has been ignited, boron is slightly soluble in water; and its solution, when evaporated to a certain point, forms a gelatinous mass, which, by complete desiccation, becomes opaque, and assumes the usual appearance of boron.

#### COMPOUND OF BORON WITH OXYGEN.

##### *Of Boric\* or Boracic Acid.*

1347. The means of procuring this acid have been mentioned in describing the process for obtaining boron. Borax is a biborate of soda, from which boric acid may be liberated in crystals, as above described, by the superior affinity of sulphuric acid for the soda.

1348. *Properties.*—Boric acid is crystalline as first obtained from borax, but forms a glass when deprived by heat of its water of crystallization. It is colourless, inodorous, almost tasteless, and sparingly soluble in water. In the form of an aqueous solution, its agency is weak, and it is in consequence rarely used in that state. In common with silicic, phosphoric, and arsenic acid, being fixed at temperatures at which sulphuric and nitric acid are decomposed, it will at those heats expel them from their combinations; although, when water is present, and at low temperatures, it is displaced from combination not only by those acids, but by many others. It consists of one atom of boron, and three of oxygen.

1349. Boron, in its habitudes, seems to lie between phosphorus and carbon. In its insusceptibility of volatili-

\* I agree with the French chemists and Berzelius, in employing the word *boric* instead of *boracic*, as more naturally generated from boron, by analogy with the other acids formed with radicals, to the last letter of which the letters *ic* are usually added.





*Apparatus for the Evolution of Silicon.*



tion, infusibility, and the temperature requisite for its combustion, it is most allied to carbon; yet boric acid is more analogous to phosphoric than to carbonic acid. Both phosphoric and boric acid are capable of being reduced to a vitreous state, and bear a white-heat without being volatilized; while the acid of carbon is naturally gaseous.

1350. Boric acid and the biborate of soda are of great use in blowpipe assays, as fluxes, and in soldering, as the means of protecting metallic surfaces from oxidation.

### *Experimental Illustrations.*

1351. Saturated solution of borax, decomposed by sulphuric acid. Exhibition of crystals of the acid and of the borate, which are severally fused into a glass by the open blowpipe. Effects of cobalt and manganese on the colour of the glass, of which a globule is conveniently supported by a platinum wire.

### *Of Chloride of Boron.*

1352. The chloride of boron may be obtained by the combustion of boron in chlorine; or by passing a current of chlorine over a mixture of charcoal and boric acid, heated to redness in a porcelain tube.

1353. The chloride of boron is a colourless gas, possessing a strong and peculiar smell. When brought in contact with water, a reciprocal decomposition takes place, and boric and chlorohydric acid result. It forms a white salt with ammonia, and is by some chemists considered as an acid.

## SECTION VI.

### OF SILICON.

1354. *Preparation.*—By heating sulphuric acid with a mixture of powdered Derbyshire spar, and powdered glass, or quartz, a permanent gas may be obtained. When potassium is heated in this gas, silicon is evolved.

### *Apparatus for evolving Silicon from Fluosilicic Acid Gas by means of Potassium.*

1355. This apparatus is represented by the opposite engraving. Into a stout mahogany block as a basis, two iron rods, A A, are so planted as to extend perpendicularly, and of course parallel to each other, about two feet in height. Upon these two iron rods are supported horizontally, one B, near their upper extremities, and the other, at the height of about six inches from the wooden basis. In the centre of the lower bar, there is a screw, D, having a handle below the bar, and supporting a circular wooden block. Into a hole in the upper iron bar, equidistant from the rods, is inserted a hollow brass cylinder, C, which at the lower end screws into

an aperture in a circular plate of brass, E, which is thus supported horizontally a few inches below the bar. By these means, room is allowed for the insertion of the cylinder of four valve cocks, each furnished with a gallow's screw. The cylinder is surmounted by a stuffing-box, F, through which a copper sliding-rod, G, passes air-tight. The brass plate is turned and ground to fit a bell glass of about five inches in diameter, and eight inches in height, which is pressed up when necessary between the plate and the block, by the screw, D, supporting the block. Within the bell glass, and on one side of the centre of the plate, two brass wires are inserted, one of them insulated by a collar of leathers, so as to reach the ignition, by a galvanic discharge, of a small arch of platinum wire, which reaches from one to the other. The sliding-rod abovementioned as occupying the stuffing-box, terminates below the plate in an elbow which supports a cup at an angle to the rod, at the same distance from the rod as the platinum wire; at the opposite side of it, there is a brass cover, H, for the cup, supported from the plate. The arrangement is such, that by a suitable movement in the sliding-rod made by grasping it by the handle, G, in which it terminates externally, the cup may be made either to receive into its cavity the platinum wire, or to adjust its cover, H.

1356. The bell being removed, about sixty grains of potassium, in pieces not containing more than fifteen grains each, are to be introduced into the cup, which is then to be adjusted to the cover, and the bell secured. In the next place, by means of the flexible lead tubes, P, P, P, P, and the gallow's screws attached to the cocks, established a communication severally with an air pump, a self-regulating reservoir of hydrogen, a barometer gauge, and a jar over the mercurial cistern, containing fluosilicic acid gas. First, by means of the air pump, exhaust the bell, in order to wash out all remains of atmospheric air, admit hydrogen from the reservoir. Again exhaust, and again admit hydrogen. Lastly, exhaust the bell of hydrogen, and admit the fluosilicic acid gas. By means of the gauge, the exhaust is indicated and measured, and by the same means it will be seen when the pressure of the gas within the bell approaches that of the atmosphere. When this takes place, the cocks being all closed, and by means of the process of galvanic ignition, &c.) the platinum wire being rendered incandescent, the potassium is to be brought into contact with it. A peculiar deep red combustion ensues, evolving copious chocolate-coloured fumes, which condensing into flocks of the same hue, descend throughout the receiver, and are deposited upon the interior surface, so as to excite in the mind of the spectator, the idea of a miniature fall of chocolate-coloured rain. On removing the bell after the potassium has ceased to burn, the cup which he is found to contain silicon mixed with the fluoride of potassium, and with the whole of the chocolate-coloured deposition is contaminated. Silicuret of potassium is likewise found in the cup; since, upon the affusion of water, a fetid inflammable gas is evolved, which has an odour resembling that of phosphoretted hydrogen, which must obviously be the analogous compound silicuretted hydrogen. The silicon, being insoluble, may be separated from the fluoride by digestion in water. The potassium employed is of the kind obtained by means of charcoal, the silicon as Berzelius alleges, adulterated with carbon. I am under the impression that nitric acid removes this impurity.

### *Simple Process for the Evolution of Silicon.*

1357. Last winter I was enabled to adopt a much more simple and convenient process for the evolution of silicon, which is as follows:

1358. A bell glass was filled, over mercury, with fluosilicic acid. By means of a bent wire a cylindrical cage of wire-gauze, containing a globule of potassium, was introduced through the mercury into the centre of the bell, and supported in a central position. A knob of iron was welded to the end of a rod, of the same metal, so recurved as to reach the cage with ease. Having been heated nearly white-hot, this knob was pushed through the mercury, so as to touch the cage. By these means the potassium having been made to enter into combustion with the fluorine, the silicon was evolved. Much of this substance remained attached to the cage in combination with fluoride of potassium. From the impurities, with which it was thus associated, the silicon was separated by washing in water and digestion with nitric acid. There can be no doubt that this process

be employed to evolve boron, by employing fluoboric acid instead of fluosilicic acid.

**1359. Properties of Silicon.**—It is of a brown-ash colour, without the least trace of metallic lustre, a non-conductor of electricity, infusible, and incapable of being volatilized. It is not liable to be dissolved or oxydized by sulphuric, nitric, chlorohydric, or fluohydric acid, but is soluble in a mixture of nitric and fluohydric acid. When heated to redness with the fixed alkaline carbonates, it burns vividly; and when dropped upon the hydrates of potash, soda, or baryta, while in a state of fusion, it explodes. Yet it is unchanged by ignition with chlorate of potash, and exercises but a feeble reaction with nitre, even when heated to redness. In these respects its habitudes are anomalous.

**1360.** When silicon, as usually obtained by the aid of potassium, is intensely heated in the air or in oxygen gas, it burns with a feeble blue flame; but, by becoming encrusted with silicic acid, a portion escapes combustion. This portion is rendered harder, denser, and insusceptible of combustion with oxygen at the highest temperatures. Berzelius suspects the greater combustibility, and inferior density and hardness of silicon, in the state in which it is obtained by the process above described, to be due to the presence of hydrogen, derived from the water employed. In this state, it inflames when ignited in the vapour of sulphur, and forms a sulphide, which is decomposed by water into sulphydric and silicic acid.

#### COMPOUND OF SILICON WITH OXYGEN.

##### *Of Silica, or Silicic Acid.*

**1361.** One atom of silicon with one atom of oxygen, each equivalent to 8, forms one atom of silicic acid, equivalent 16.

**1362. Preparation.**—Quartz being powdered, and fused with three times its weight of pearlash, a glass is obtained, which, being soluble, forms with water a liquid, called formerly liquor silicum, or liquor of flints. An acid being poured into this solution, silicic acid, slightly contaminated by potash, is precipitated.

**1363.** To obtain silicic acid, Berzelius advises us to fuse in a platinum crucible, equal parts of the carbonates of

potash and soda, and to add quartz, finely pulverized, in small successive portions. The effervescence arising from the addition of one portion, is allowed to subside before adding another, until effervescence can no longer be excited. The refrigerated mass is dissolved in chlorohydric acid, and the solution filtered and evaporated to dryness. To remove all traces of iron or alumina, the dry mass is kept moist with chlorohydric acid, during about two hours, and afterwards washed with hot water, and then exposed to a red-heat. Silicic acid will remain in a sufficient degree of purity.

1364. Pure silicic acid, in the well known form of rock crystal, is found throughout nature. Its usual crystalline form is a six-sided prism, terminated by a pyramid with six faces.

1365. *Properties.*—Pure silicic acid is white, tasteless, and inodorous, and has a specific gravity of 2.66. Its solution does not redden litmus, and, when evaporated to a certain point, forms a translucent jelly. It is soluble when nascent, but insoluble after exposure to heat or desiccation, or in its native crystalline form.

1366. It was first fused by myself, in the year 1801, by means of the compound blowpipe. It has never been volatilized.

#### *Of Chloride of Silicon.*

1367. When silicon is heated in chlorine it inflames, evolving heat and light, and a chloride of silicon is formed, which is a volatile liquid, possessing a sharp and powerful odour. In consequence of the absorption of an excess of chlorine, it is generally coloured yellow. It boils below  $212^{\circ}$ , and, by the addition of water, is converted into chlorohydric and silicic acid.

#### *Experimental Illustrations.*

1368. Silicate of potash, exhibited; also the solution of it, called liquor silicum, from which silica is precipitated by means of an acid.

#### *Of Glass.*

1369. If the proportions, in which sand and alkali are used as above-mentioned for the liquor silicum, be reversed, the insoluble compound of silicic acid and alkali, known under the name of glass, is obtained, which, however pure the materials, has a slight tinge of green. This is removed by a due admixture of the red oxide of lead, and black oxide of manganese.

1370. *Annealing Process.*—A sudden diminution of the quantity of

c among the exterior particles of a thick piece of glass in a state of fusion, is not attended by a corresponding diminution of the quantity of principle among the particles within, owing to the slowness with which it conducts heat. Hence, there can neither be a general coherence, nor a uniform arrangement among the particles; unless the cooling be very gradual, so as to allow the refrigeration, within and without, to be nearly simultaneous. As it never can be perfectly simultaneous, the annealing ways be defective, other things being equal, in proportion as the glass is thicker. Were the particles subjected to radiant heat only, the process would be more effectual; as this, when proceeding from incandescent surfaces, has been ascertained to penetrate and even to pass through glass.

71. By gradually making up a fire of charcoal, at about four inches distance on each side of a glass tube of about an inch and a quarter in diameter, and with a very small bore, I was enabled to heat it red-hot, without causing a fracture. From its situation, it was subjected to radiant heat only.

72. By opening a perpendicular hole in an anthracite fire, I have been enabled, with little delay, to introduce the beaks of glass retorts of two or three gallon in capacity, without causing a fracture. Thus situated, the glass soon becomes almost fluid, so that by its own weight the lower portion is drawn downwards into a tapering tube, and would be made to fall if the beak not removed from the fire. If removed in due time, the neck of the retort may be so held as to cause the tapering portion of the neck to form such an angle with the other part, as to be capable of entering the tubulure of another retort, as described in one of the processes for producing pure chlorohydric acid. (891.)

73. By like means, the beaks of broken retorts, or any piece of a glass retort may be made to taper, to be elongated so as to be inserted through the tubulure of a retort, and to serve, consequently, when luted to the tubulure for the introduction of sulphuric acid, in various processes besides that in which allusion is above made.

74. *Prince Rupert's Drops*.—When glass, in a state of fusion, is suddenly cooled into water, the defective states of cohesion and arrangement, consequent to the want of annealing, are at the maximum. Such drops have been known under the name of Prince Rupert's drops. It is only necessary to break off the slender filament in which the mass terminates, in order to cause an explosive dispersion of the whole into a coarse powder.

75. The cohesion of the particles in glass tubes, is often nearly as intimate as in Prince Rupert's drops. The slightest mark from a file on the exterior surface, or even wiping them out, especially if a metallic wire be employed, may cause them to break into pieces. Sometimes the fracture occurs immediately, at other times, not till many hours have intervened.

#### COMPOUNDS OF FLUORINE WITH HYDROGEN, BORON, AND SILICON.

76. Fluorine has been briefly noticed, (746, &c.) I intend treating of the interesting compounds formed by this element with hydrogen, boron, and silicon, until the reader should be acquainted with those substances.

77. The three fluorides referred to are called *sevefluohydric*, *fluoboric*, and *fluosilicic acid*. (862).

*Of Fluohydric Acid, generally called Hydrofluoric Acid. (858.)*

1878. Fluorine exists in nature in union with the metals of the earth and alkalies, especially with calcium, a metal of which lime is the oxide. Such compounds are called fluorides. The remarkable mineral, called Derbyshire or fluor spar, is a fluoride of calcium.

1879. Not long since, Derbyshire spar was considered a compound of lime with an acid, called fluoric acid, and supposed to consist of oxygen and an unknown radical. Mr. Ampere first suggested the present doctrine, which was soon adopted by Sir H. Davy, and is now, I believe, universally sanctioned.

1880. *Preparation.*—When fluoride of calcium is pulverized, and heated in a leaden retort with twice its weight of concentrated sulphuric acid, the water in combination with the acid is decomposed. The oxygen and acid form sulphate of lime with the calcium; while the hydrogen produces with the fluorine, fluohydric acid, which passes over in the form of a very volatile acid vapour, and may be condensed in a leaden or silver receiver, surrounded by a mixture of snow and salt. If received in water, it condenses without refrigeration, and forms a diluted acid.

1881. *Properties.*—Fluohydric acid is a colourless, limpid liquid, which boils at a little below 60°. When anhydrous, its specific gravity is 1.0000. It is so volatile, that, in a close apartment it cannot be decanted without subjecting the operator to intolerable fumes. This operation must be performed where there is a current of air to carry them off.

1882. It ulcerates the skin with peculiar activity, and corrodes glass so as to trace its course indelibly, in running over the surface. It must be kept in vessels of silver or lead, accurately closed. When received in water it is absorbed, forming aqueous fluohydric acid, and is then more easily preserved.

1883. One atom of hydrogen, equivalent 1, with one atom of fluorine, equivalent 18, is supposed to form one atom of fluohydric acid, equivalent 19.

*Experimental Illustrations.*

1384. Powdered fluoride of calcium, heated with sulphuric acid in a leaden retort, adapted to a receiver surrounded by a mixture of snow and salt. Same process, substituting a receiver with water, by means of Knight's apparatus. Effect of fluohydric acid upon glass.

*Of Fluoboric Acid.*

1385. *Preparation.*—It may be obtained by intensely heating a mixture of two parts of powdered fluoride of calcium, with one of vitrified boric acid, in an iron tube. One part of the boric acid is decomposed, the oxygen of which, and the remaining portion of the acid, form borate of lime with the calcium; while the boron unites with the fluorine, forming fluoboric acid gas, which must be received over mercury. Fluoboric acid gas, may likewise be procured, by heating in a glass retort two parts of fluoride of calcium and one of boric acid, with twelve parts of concentrated sulphuric acid. Berzelius, however, states that, when obtained by this method, it is contaminated by fluosilic acid, arising from the action of the fluorine on



25. This might, however, be avoided by performing the operation in a retort.

26. Dr. Thomson states that the best method of obtaining fluoboric acid is one which was suggested by Berzelius. Boric acid is to be dissolved in anhydrous fluohydric acid, and a gentle heat applied to the solution. A reciprocal decomposition takes place; the hydrogen of the fluohydric acid combines with the oxygen of the boric acid, forming water, and the fluorine unites with the boron, and constitutes fluoboric acid gas.

27. *Properties.*—Fluoboric acid is a colourless, transparent gas, with a pungent odour, and an acid taste. It reddens litmus paper, and is destructive to organic matter. Its specific gravity is 2.3622. Water absorbs seven hundred volumes of this gas. When fluoboric acid is passed into water, a portion of the water unites with the boron, forming boric acid, while the hydrogen combines with the fluorine, producing fluohydric acid. The boric acid precipitates, and the fluohydric acid combines with the decomposed portion of the fluoboric acid, forming a compound which is designated as hydrofluoboric acid, but which, according to the nomenclature which I have adopted, should be called *fluohydroboric acid*. To continue to pass fluoboric acid gas into the water, or partially abstract it by evaporation, until the solution of fluoboric acid becomes saturated, the affinities which were at first brought into play are reversed. The hydrogen of the fluohydric acid unites with the oxygen of the precipitated boric acid, and the fluorine with the boron; so that we finally obtain a solution of fluoboric acid in water. This solution is at first fuming; the application of heat it yields up a fifth part of its gas, and then it resembles concentrated sulphuric acid in appearance. Like that acid, it carbonizes organic products, in consequence of its affinity for water.

28. Three atoms of fluorine, equivalent 54, and one atom of boron, equivalent 11, form one atom of fluoboric acid, equivalent 65. (856, &c.)

### Of Fluosilicic Acid.

29. *Preparation.*—It may be obtained by adding to the materials for the preparation of fluohydric acid, one half their weight of finely powdered glass, and the mixture to heat in a glass retort, and receiving the product in mercury; as by water it would be rapidly absorbed.

30. The oxygen of the silicic acid in the glass, with the sulphuric acid, forms a sulphate of lime; while the fluorine and silicon escape in the form of fluosilicic acid gas.

31. The apparatus which I employ for fluosilicic acid, is precisely the same as that described under the head of ammonia.

32. *Properties.*—Fluosilicic acid is a transparent, colourless gas, with a sharp and suffocating odour, closely resembling that of chlorohydric acid. It reddens litmus paper, and has a specific gravity of 3.5735. When it is in contact with water it is rapidly absorbed, and a decomposition takes place, similar to that which ensues in the case of fluoboric acid under the same circumstances. Silicic acid is deposited in the form of a gelatinous substance, and fluohydric acid is produced, which combines with the undecomposed portion of the fluosilicic acid, forming a compound called hydrofluosilicic acid, to which, if it be an acid, I would give the name of *fluohydrofluosilicic acid*. If the water in combination with the fluohydrofluosilicic acid be removed by heat, fluosilicic acid gas escapes, leaving fluohydric acid solution.

1394. One atom of fluorine, equivalent 18, with one atom of silica, equivalent 8, forms one atom of fluosilicic acid, equivalent 26.

### *Experimental Illustrations.*

1395. Production of fluosilicic acid, shown: also its absorption by water, and the precipitation of silicic acid, as above described.

#### *Of the Reaction of Fluohydric Acid with Fluoboric and Fluosilicic Acid, and of the Nomenclature of the Compounds formed by the latter on meeting with Oxibases.*

1396. The union which ensues between fluohydric acid, and either fluoboric, or fluosilicic acid, agreeably to the preceding statement, may appear anomalous, in the way in which it has hitherto been treated. If, however, I am correct in my mode of defining the difference between an acid and a base, (631,) the combinations in question will not prove to be anomalous. I deem it consistent to suppose that a fluobase of hydrogen unites, in the one case, with fluoboric acid, in the other with fluosilicic acid; so that fluohydroboric acid might be called fluoborate of the fluobase of hydrogen, or more briefly, fluoborate of hydrogen; and in like manner, fluohydrosilicic acid would be called fluosilicate of the fluobase of hydrogen, or briefly, fluosilicate of hydrogen.

1397. When either fluohydroboric acid, or fluohydrosilicic acid, or in other words the fluoborate or fluosilicate of the fluobase of hydrogen, is brought into contact with an oxibase, the radical of the latter takes the place of the hydrogen, which, with its oxygen, forms water. Thus, in the case of potash, there would result a fluobase of potassium, usurping the place of the fluobase of hydrogen; and of course either a fluosilicate, or fluoborate of potassium must be formed. Agreeably to the Berzelian nomenclature, these compounds are double salts, the name of one being in the French translation, "*fluorure borico-potassique*," that of the other, "*fluorure silico-potassique*." Many analogous salts, formed by the acids under consideration, with salifiable substances, are mentioned by Berzelius; also many others, in which other radicals, in union with fluorine, play a part analogous to that performed by silicon and boron, in the salts above mentioned.

1398. There are instances in which compounds, usually called bases, act as acids. Of course it is consistent that compounds, usually called acids, should in some instances act as bases. In this respect, a striking analogy may be observed between the union of the oxide of hydrogen (water) with the oxacids and oxybases; and that of fluoride of hydrogen with fluacids and fluobases. According to Berzelius, water acts as a base to oxacids; as an acid to oxibases. So I conceive the fluoride of hydrogen acts as a base in the cases above noticed, while it acts as an acid in the compound of hydrogen, fluorine, and potassium, called by Berzelius "*fluorure potassique acide*." This compound I would call a fluohydrate of the fluobase of potassium, or more briefly, fluohydrate of potassium; as we say sulphate of copper, instead of the sulphate of the oxide (or oxybase) of copper.

## SECTION VII.

## OF ZIRCONION, OR ZIRCONIUM.

1. There is a stone, known under the name of the jargon or zirconion, from which Klaproth extricated an earth, to which the name of it was given. This earth is an oxide of an elementary body, which is called zirconion, or zirconium. The termination in um being now applied by chemists to the names of substances having the metallic character, I think that it has been erroneously associated with the name of zirconion in question, since its pretensions to that character are not higher than those of carbon.

## OF METALLIC RADICALS.

10. It is to metallic radicals that I deem it expedient to next place to direct attention. Less than thirty years ago, the line of demarcation between metals and non-metals was easily drawn. There was then no known metal which had a specific gravity less than six; and of non-metals, none of which the specific gravity was as low as five. But the discovery of alkalis and metallic acids, having a specific gravity less than that of water, obliterated the barrier which had been established on the basis of superior gravity.

11. Peculiar brilliancy and opacity were in the next place appealed to as the means of discrimination; and likewise that superiority in the power of conducting heat and electricity, which was so remarkable in substances of a truly metallic character. Yet so difficult has it been to draw the line between metallic and non-metallic radicals, that bodies which are by some authors placed in one class are by others included in the other. Thus selenium, silicon, and zirconion have by some chemists been ranked among the metals, by others among non-metallic radicals. In fact nature has not qualified her bodies for exact classification. It is true that there are those of which the prominent features or qualities are so strikingly distinct, that we are at first encouraged to think that by comparing similar substances with each, we shall form a classification not liable to be confounded. Thus gold possesses, in a high degree, all the attributes of a metal, while sulphur is wholly devoid of them; yet arsenic, as being decidedly metallic, may on the one side be classified with gold in

preference to sulphur; while on the other hand, between arsenic and sulphur, there is in many respects a much greater analogy than between arsenic and gold. In fact, tellurium, which had been always classified and is still considered as a metal, is now associated by Berzelius, in his amphigen class, with oxygen, selenium, and sulphur, and has, in consequence, been treated of by me as a basigen body.

1402. Metals were formerly distinguished as metals, and semi-metals; the latter appellation having been employed to designate such as were wanting in the mechanical properties of malleability and ductility. Again, the metals which were endowed with the properties just mentioned, were divided into noble and base. The noble metals, sometimes called precious, from their superior value, were distinguished from the others by their insusceptibility of injury from fire, moisture, or air. Silver and gold were, about a century ago, the only known metals meriting the name of noble, upon the grounds which I have mentioned. To these platinum was subsequently added, and latterly palladium, nickel, iridium, and rhodium, have been found to have analogous pretensions, agreeably to the ideas in obedience to which the epithet was originally employed. Subsequently chemical properties became better known, and metals were associated not only in accordance with their own obvious characteristics, but also with a view to their oxides, which in many cases are the only forms under which they are met with in nature, or employed in the arts. Accordingly the metals are now generally divided with a view to their susceptibility of oxidizement, or the character of their oxides. Among the oxides alluded to, there are some of which the characteristics are so different, that there can be no hesitation in classifying them separately. Yet in other members of the same class, the characteristics by which they are distinguished are so feeble, that a diversity of opinion has existed as to the genera to which they belong.

1403. I propose to divide metallic radicals into the four following classes:

First, *metals of the earths proper.*

Second, *metals of the alkaline earths.*

Third, *metals of the alkalis, or alkalifiable metals.*

Fourth, *metals proper.*

1. I shall employ the words noble to distinguish not liable to be tarnished by exposure to fire, or air; as, for instance, gold, platinum, iridium, rhodium, silver, and nickel.

2. Metals proper are by Berzelius divided into elective or acidifiable metals, and electro-positive or noble metals. Under the former head he places selenium, arsenic, molybdenum, tungsten, antimony, tellurium, niobium or tantalum, and titanium. Under the head of electro-positive or basifiable metals, he places gold, platinum, iridium, palladium, silver, mercury, copper, iron, tin, lead, cadmium, zinc, nickel, cobalt, manganese, and uranium.

3. I am under the impression that each of the following metals, being, agreeably to the same authority, capable of forming with a halogen body the electro-negative ingredient in a double salt, should be considered elective; namely, gold, platinum, silver, palladium, rhodium, uranium, chromium, titanium, molybdenum, manganese, osmium, mercury, nickel, copper, iron, &c.

4. When the objects which it may be desirable to examine are too numerous and complicated in proportion to the time and attention which we have to bestow; we may, at such time as we have, either in a cursory, superficial and indiscriminate examination of the whole, or in a thorough study of the more important parts. Of these two courses I cannot conceive that any judicious person would hesitate in choosing the latter.

5. Under this impression I shall treat particularly of the elective metals proper, included in the following list—gold, platinum, silver, mercury, copper, lead, tin, iron, zinc, manganese, bismuth, and arsenic. Besides the metals thus named, there are in the same class, palladium, rhodium, iridium, osmium, nickel, cadmium, chromium, cobalt, iron, tin, manganese, molybdenum, titanium, tungsten, niobium, and vanadium. Of these I shall give only a brief account, with descriptions and illustrations of their uses; and useful properties, where such exist.

I subjoin a list of metallic radicals, comprising all the metals known; tellurium; which has been treated of as a basacigen element. For our knowledge extends, the dates at which these metals severally were discovered, and the names of their discoverers, are mentioned.

*Table of Metals classified as Metallic Radicals, also of the dates at which they were discovered.*

Names of Metals.	Authors of the discovery.	Dates of the Discovery.
Gold . . . . .	Known to the Ancients.	
Silver . . . . .		
Iron . . . . .		
Copper . . . . .		
Mercury . . . . .		
Lead . . . . .		
Tin . . . . .		
Antimony . . . . .	Described by Basil Valentine . . . . .	1490
Bismuth . . . . .	Described by Agricola . . . . .	1530
Zinc . . . . .	First mentioned by Paracelsus . . . . .	16th century.
Arsenic . . . . .	Brandt . . . . .	1733
Cobalt . . . . .		
Platinum . . . . .	Wood, assay-master, Jamaica . . . . .	1741
Nickel . . . . .	Cronstadt . . . . .	1751
Manganese . . . . .	Gahn and Scheele . . . . .	1774
Tungsten . . . . .	D'Elhuyart . . . . .	1781
Molybdenum . . . . .	Hielm . . . . .	1782
Uranium . . . . .	Klaproth . . . . .	1789
Titanium . . . . .	Gregor . . . . .	1791
Chromium . . . . .	Vauquelin . . . . .	1797
Columbium . . . . .	Hatchett . . . . .	1802
Palladium . . . . .	Wollaston . . . . .	1803
Rhodium . . . . .		
Iridium . . . . .	Descotils and Smithson Tennant . . . . .	1803
Osmium . . . . .	Smithson Tennant . . . . .	1803
Cerium . . . . .	Hisinger and Berzelius . . . . .	1804
Potassium . . . . .	Davy . . . . .	1807
Sodium . . . . .		
Barium . . . . .		
Strontium . . . . .		
Calcium . . . . .	Stromeyer . . . . .	1818
Cadmium . . . . .		
Lithium . . . . .	Arfwedson . . . . .	1818
Aluminium . . . . .	Wöhler . . . . .	1828
Glucinium . . . . .		
Yttrium . . . . .	Berzelius . . . . .	1829
Thorium . . . . .		
Magnesium . . . . .		
Vanadium . . . . .		
	Bussy . . . . .	1829
	Sefström . . . . .	1830

*Of the Generic Characteristics of the Metals.*

1410. When newly cut, metals have a peculiar lustre. They are the best conductors of heat and electricity; the worst radiators and best reflectors of heat. All combine, directly or indirectly, with all the basigen bodies in one or more proportions. (633.) They are all susceptible of solidity and fluidity, and probably of the æriform state. Mercury and arsenic are easily volatilized; and gold, silver, and platinum, though very difficult to burn or volatilize, are nevertheless dissipated by means of the compound blowpipe, galvanism, or electricity.

*Of Properties possessed by some Metals, but not by others.*

1411. The properties which come under this head, are permanency of lustre in the fire and air; malleability; ductility; elasticity; sensibility to

to magnet; susceptibility of the welding process, and of acquiring, by a fusion with carbon, silicon, or aluminium, the capability of hardening by being suddenly refrigerated from a red-heat; also of being hardened by a hammer, and of being restored by heat in the annealing process.

1412. The metals remarkable for permanency of lustre, are gold, platinum, iridium, palladium, rhodium and nickel, called on that account noble, perfect. Those principally remarkable for malleability, are gold, silver, tin, copper, palladium, nickel, iron, tin, cadmium, and lead. Among these, iron and platinum only, can be advantageously hammered at a very high temperature.

1413. The metals distinguished for elasticity, are iron, copper, and steel. Iron, in the state of steel when duly tempered, is pre-eminent for this property.

1414. The metals remarkable for ductility, are gold, iron, either pure, or as steel, silver, copper, platinum, tin, and lead. In large rods or pipes, iron and tin are the most ductile.

1415. The magnetic metals are iron, whether pure, in the state of steel, or in that of protoxide, nickel, and cobalt. Those susceptible of the welding process, are iron and platinum. Iron only is capable of uniting with carbon, silicon, or aluminium, and hardening consequently by quick refrigeration. Gold and platinum are distinguished by their superior gravity, which is between two and a half, and three times as great as that of iron, copper, or zinc.

1416. All the metals have a specific gravity greater than five, if we except those of the earths and alkalis.

1417. *Of the Annealing Process.*—Malleability, ductility, and toughness, in metals susceptible of the annealing process, are probably dependent on the quantity of caloric remaining in combination with their particles, while in the solid state. When malleable metals are hammered, they give out heat, and become harder, more rigid, elastic, and dense, until they acquire a certain maximum of density. This being attained, they are fractured if the hammering be carried further. Exposed to the fire until softened, they are found on cooling to have regained the properties of which percussion had deprived them; and they may be again condensed, heated, and hardened, by the hammer.

1418. *Of Alloys.*—This name is given to the compounds formed by the union of different metals. There is always copper in gold and silver coin; and in the metal employed under those names by the smiths and jewellers, there are various proportions of the baser metal. Brass consists of copper and zinc; pewter, of lead and tin, or of tin, copper, and antimony.

*Of the Oxidability of Metals by Exposure to Air or Moisture, with or without Heat.*

1419. Gold, silver, platinum, palladium and rhodium, do not become oxidized by exposure to water or oxygen at any temperature; and when oxidized by other means, on being ignited are reduced.\*

\* The verb to *reduce*, has long been employed by chemists to signify the deoxidation of a metallic oxide, so as to effect its restoration to the metallic state, or that of a *regulus*, to use another word which I shall also employ, to avoid circumlocution; although it is now somewhat antiquated. The verb to *revive* has been used in the same sense as to reduce.

1420. Iron, zinc, and tin are not oxidized by exposure to dry air, or to water alone, unless aided by a red-heat. Of these metals iron is most acted upon by the joint influence of air and moisture, at the ordinary temperatures of the atmosphere. Copper, tin, and lead do not decompose water at any temperature, but are oxidized at a red-heat, or at temperatures sufficient for their fusion. Mercury is not oxidized by water under any circumstances. It is oxidized by agitation, or by a heat just below its boiling point, with access of air; but when distilled, it abandons the oxygen which may have united with it previously.

#### OF METALS OF THE EARTHS PROPER.

1421. The metals included under this head are *aluminium, glucinium, yttrium and thorium*.

#### SECTION I.

##### OF ALUMINIUM.

1422. A chloride of aluminium was obtained by Oersted by subjecting to a current of chlorine, an intimate mixture of alumina and carbon, heated in a porcelain tube. The affinity of the carbon for the oxygen of the earth, and of the chlorine for the metallic radical, was productive of carbonic oxide in the state of gas, and the chloride of aluminium in the state of vapour; of course the former escapes, while the latter condenses, within a glass tube purposely luted to that in which the materials are ignited, as already explained.

1423. By heating, with potassium, the chloride obtained by the process above mentioned, Wöhler liberated aluminium through the superior affinity of potassium for chlorine.

1424. I have repeated this process so far as to obtain the chloride, and to expose it to reaction with potassium, but I found it difficult to extract the aluminium from the residual mass to a satisfactory extent.

1425. *Properties of Aluminium.*—In the state in which Wöhler obtained this metal, it is described as a gray powder much resembling that of platinum. Some little facets, which have sufficient magnitude to be distinguished, after compression under the burnisher, display a metallic brilliancy. Yet in the pulverulent form, the metal has so little power to conduct electricity, that, when interposed in the galvanic circuit, it interrupts the action. It is alleged, however, that, in a minute state of division, iron is a non-



tor of electricity, and Turner states that, by fusion, it becomes a conductor. It appears to me that its claims to the metallic character are not superior to those of carbon in the form of plumbago. Its atomic weight is 14.

Aluminium burns with a heat so intense, as to melt the fusion of the resulting oxide, which becomes, on cooling, hard enough to cut glass. Aluminium is not oxidized when water is evaporated from it at a gentle heat. On boiling heat it evolves hydrogen feebly, and the evolution having once commenced, continues for some time without refrigeration. With concentrated nitric or sulphuric acid, aluminium has no reaction at ordinary temperatures; assisted by heat, it forms a sulphate or nitrate, and liberates oxygen from one portion of the acid, and uniting with the remainder. When subjected to a solution of potash, or ammonia, aluminium, by the decomposition of water, is converted into alumina, which unites with alkali, forming an aluminate. On this account, in preparing aluminium, there should not be an excess of potash, and any potash produced during the process, should be promptly removed by the employment of a quantity of water no larger than necessary.

### *Of Alumina.*

This earth is found nearly pure in the gems called corundums, oriental, and classed by Brongniart, under the name of Corindon Telesie. The ruby, sapphire, amethyst, &c., of the most beautiful kinds, are thus designated. Among stony minerals they have the highest specific gravity, and are only inferior to the diamond in hardness. Differing from each other only in colour, they yield by analysis to little else than pure alumina. There are other jewels of the same name and colour, which ought not to be confounded with those here alluded to. As an ingredient in which it owes its plasticity and all its striking qualities to silica, this earth enters largely into the structure of the terrestrial globe.

The spinelle ruby, a precious stone, and Gahnite, or spinel,—the former of magnesia, the latter of alumina, in which, however, there are six times as many atoms of alumina, as of the other constituent.

1429. There are two native forms of hydrate of alumina, one found in the United States, in the form of a stalactitic white and semitransparent, called Gibbsite; the other in Siberia, called diaspor, from the property of flying in pieces, or even powder, when heated, in consequence, doubt, of the vaporization of the combined water.

1430. *Preparation*.—Berzelius alleges that the alumina in commerce, if it contain oxide of iron, should be dissolved and recrystallized several times; or a solution being made and allowed to stand for some time, the oxide of iron is precipitated in yellow flocks. To the solution of alumina on a boiling heat, a solution of carbonate of potash is to be added in excess, and the whole is to be digested at a moderate temperature, to decompose any supersulphate of alumina which the alkali may have precipitated. The precipitate, after having been collected and well washed, is to be upon a filter, is to be redissolved in chlorohydric acid and precipitated by an excess of ammonia, either carbonate or carbonated. This second precipitation is necessary to get rid of a portion of carbonate of potash, with which the alumina forms a triple combination which cannot be decomposed by water. The precipitate produced as mentioned, is to be collected and carefully washed. When dried it forms a hydrate, which, by a red heat, is converted into pure alumina. One hundred parts of alumina yield a little more than ten of the earth.

1431. In France a species of alum is used, in which ammonia takes the place occupied by potash in the common alum. By heat, which expels the acid and ammonia, pure alumina may be extricated from this compound.

1432. *Properties*.—Alumina is white, plastic when moistened, soft to the touch, adherent to the tongue, inodorous, insipid, and infusible in the furnace. It is the only earth which was fused before the compound blowpipe was invented. Its property of contracting and hardening on heat, was noticed when on the subject of Wedgwood's pyrometer.

1433. It is remarkable that, although quite insoluble in water, this earth abstracts and retains a quantity of water amounting to 15 per cent. of its weight. It is on account that, as an ingredient in clay, its influence on vegetation is so beneficial. During rains it becomes

with moisture, which it slowly relinquishes in dry

There is a remarkable difference in the appearance of the hydrate of alumina as obtained by precipitation from a concentrated, or a weak solution of alum. In the former case it is a white, friable, spongy powder, which is soft to the tongue, and, by exposure to a red-heat, loses all its water. In the latter it forms a transparent mass, which breaks by the heat of the hand into a smooth and conchoidal fracture, does not adhere to the tongue, or swell by the addition of water. In this case the hydrate of alumina does not part with all its water even at a temperature above that of redness.

Alumina has a great affinity for vegetable colour-matters, which it consequently precipitates from their solutions, forming the pigments known under the name of

This earth and its salts are of great use in dyeing mordants to cause the dyes to adhere. The latter, in some cases, have no affinity for the organic fibres which are dyed; but the alumina, combining with both the fibre and the dye, associates them permanently.

Alumina is soluble in solutions of caustic potash, and even in those of baryta and strontia, but only in liquid ammonia, only to a very small extent. It has an affinity for oxybases so strong, as to be regarded as acting the part of an acid in some instances. The acid and base of alkaline carbonates it forms double compounds, which will bear a low red-heat without losing the acid, or producing a more intimate union between the earth and alkali.

The affinity of alumina for magnesia is so strong that they are separated simultaneously from a common solution. The former cannot be taken up entirely by the alkali, but the separation is effected. If magnesia, after having experienced a red-heat, be subjected to hydric acid, a white powder remains, which is an oxide of magnesia.

Three properties serve to detect alumina; first, its solubility in potash, and consequent solubility in a solution of alkali; secondly, the property which it has of forming a white precipitate with sulphuric acid and potash, *alum*, so readily recognised by its crystallization and taste; thirdly, the property

of producing a fine blue colour, when moistened with nitrate of cobalt, and exposed to a strong heat.

1440. In the habitudes of this substance, we have an exemplification of the commutable character of electrochemical characteristics. While with the alkalies and alkaline earths it performs the part of an acid, with various acids it acts as a base, forming with them compounds both natural and artificial. Among the former is the mineral generally designated as feldspar, which is composed of silicate of alumina, and silicate of potash. Porcelain is an artificial silicate of alumina. Its existence as a base in alum has been mentioned.

1441. Alumina was named from alumen, the Latin appellation for alum. The specific gravity of alumina is 2. It is composed of two atoms of aluminium, equivalent 28, and three atoms of oxygen, equivalent 24 = 52. It is, therefore, a sesquioxide.

### *Experimental Illustrations.*

1442. Alumina, precipitated from a solution of alum by an alkali. Rendered blue by a solution of nitrate of cobalt. Contraction sustained by exposure to heat, illustrated.

### *Of Chloride of Aluminium.*

1443. The chloride of aluminium is obtained as I have stated above. (1422.) It is partially translucent, lamellated in structure, of a greenish-yellow colour, and an astringent taste. Litmus is reddened by the action of this chloride. It dissolves in water with a hissing noise. When the solution is highly concentrated, it deposits crystals, which, being convertible by heat into alumina and chlorohydric acid, probably consist of one atom of chloride of aluminium, and one atom of water. According to Thenard, the chloride of aluminium forms, with the chlorides of potassium and sodium, compounds indecomposable by a red heat. These may be considered as formed by the union of a chloracid with a chlorobase.



## SECTION II.

### OF GLUCINIUM.

1444. Glucinium may be obtained from its oxide, glucina, by a process analogous to that above described for obtaining the radical of alumina. This metal resembles aluminium in appearance, and in many of its properties, but differs from it in not being susceptible of oxidization by a solution of ammonia, or by boiling water.

*Of Glucina.*

Glucina is white and tasteless. It is insoluble in water, but forms with it a mass which is somewhat adhesive, but not sufficiently so to be moulded. It does not lose its properties by exposure to heat.

It is soluble in the caustic fixed alkalies, but not in ammonia. It likewise dissolves in the alkaline carbonates, and in that of ammonia especially, by which it is distinguished from alumina, as well as by its incapacity to produce alum, or to assume a blue colour when treated with nitrate of cobalt. It forms also a fluoacid, with the fluoride of potassium, precipitates from a hot solution in crystalline form in the state of *fluogluconate of potassium* (fluoride glucinico-potassique of Berzelius).

The equivalent of glucina is 26, being composed of one atom of glucinium, at 18, and one atom of oxygen, equivalent 8.

Glucina exists in the emerald, comprehending the beryl and aquamarine: hence its name. In consequence of the peculiar sweetness of its salts, it was named *glucina*, from *γλυκύς*, sweet.

## SECTION III.

## OF YTTRIUM.

Yttrium was procured by a process quite analogous to that described for alumina.

It has a more metallic and crystalline aspect than that metal or glucinium. Its oxides with oxygen and the acids are perfectly analogous to those of the metals mentioned. It is liable to be slowly oxidized in a solution of potash by the decomposition of water. Like glucinium, it is not oxidized by water even when

*Of Yttria.*

Yttria is insipid, infusible, and insoluble in water. It is uncertain whether the pink tinge which it usually presents, is appropriate, or produced by impurities. It is rendered snow-white by the presence of a small quantity of sulphuric acid. It is heavier than baryta, being of a specific gravity approaching to 4.842. It is distinguished from other earths by its insolubility in caustic alkalies; while it dissolves carbonates, especially that of ammonia, although in a lesser quantity than

Yttria is principally characterized by its susceptibility of precipitation by nitrate of potassium (ferroprussiate of potash). Excepting thorina, this process is not possessed by any other earth.

With acids it forms salts, having a sweet taste, and in some instances the colour of the amethyst. In fact, the best means of detecting it, is the production of a phosphoric acid of crystals having this hue, which are extremely slow to dissolve, and which effloresce when heated. Its affinities are more feeble than those of the alkalies or alkaline earths.

This earth has been found only in three Swedish minerals,—Gadolinite, Yttro-cerite, and yttrite.

Yttrium is composed of one atom of yttrium, equivalent 32, and one atom of oxygen, equivalent 8 = 40.

## SECTION IV.

## OF THORIUM.

Thorium was first found, not many years since, in a single locality, in the island of Loeccun, combined with silicic acid. It is in the island of Loeccun, near the little village of Berwig, in Norway. It was found in a mass resembling obsidian, and called thorite, which contained 57 per cent. of oxide of thorium, and in addition, lime, magnesia, iron, manganese, os-

mium, lead, tin, and a little alkali combined with silicic acid and water. In the analysis of this mineral, Berzelius discovered thorina.

1456. From chloride of thorium, as from the other chlorides of the same genus, the radical may be evolved by means of potassium and heat. It may likewise be extricated from the double fluoride of thorium and potassium, or fluoride of potassium. Thorium, in its appearance and in many of its properties, resembles aluminium; but differs from it in not being oxidized by reaction with water, dilute sulphuric acid, or alkaline solutions. When heated gently in air, thorium inflames, and is converted into thorina.

1457. I do not conceive that either thorium, or any other of those substances enumerated as convertible by oxidization into the earths proper, are more entitled to be considered as metals, than carbon in the state of plumbago.

#### *Of Thorina.*

1458. Thorina is white, tasteless, and inodorous. In common with alumina, and yttria, it is capable of acting as a base with water. The resulting hydrate of thorina is by heat convertible into the anhydrous oxide, in a state of great hardness.

1459. Thorina may be known from its sulphate being more soluble in cold than in hot water. It is composed of one atom of thorium, equivalent 60, and one of oxygen, equivalent 8 = 68.



### OF METALS OF THE ALKALINE EARTHS.

1460. Under this head are included *magnesium*, *calcium*, *barium*, and *strontium*.

#### SECTION I.

#### OF MAGNESIUM.

1461. Magnesium was first obtained by Bussy in 1808, by subjecting the chloride to the action of potassium, in a manner precisely similar to that already described for the preparation of sodium (1422). It resembles silver in color and fusibility. It is malleable, and has a decided metallic brilliancy. It is oxidized by exposure to the air, and by boiling water. When sufficiently heated in the air, it combines with oxygen, and is converted into magnesia. Its specific gravity is greater than that of water.

#### *Of Magnesia.*

1462. This earth exists abundantly in a state of combination in nature. Dr. Thomson states that a whole range of low hills, consisting of anhydrous carbonate of magnesia, exist in India.

1463. Sulphate of magnesia is one of the salts which exist in the ocean, and, consequently, when sea water is evaporated in order to obtain common salt, the sulphate may be obtained from the mother-water. For the preparation of

re of the salt first abovementioned, magnesia has been obtained in this country, from an American mineral magnesite, which is silicate of magnesia, iron, and Many varieties of lime-stone and marble contain sia. The marble called dolomite, is especially well as a compound of lime and magnesia. The presence of magnesia renders a carbonate less ready to give carbonic acid gas.

4. This earth may be precipitated from a solution of salt, by adding a solution of potash or soda. It likewise be obtained from the carbonate by heat.

5. *Properties.*—Magnesia is white, has a feeble alkalescent, and affects vegetable colours like an alkali, feebly. (1070.) It is nearly insoluble in pure water, dissolves to a considerable extent in water containing carbonic acid, forming a soluble supercarbonate.

6. Magnesia is distinguished from the other alkaline earths not only by being less energetic in its affinities and alkaline properties, but by the solubility of its sulphate.

7. Magnesia is one of the most fixed and refractory substances in nature, and was deemed infusible until fused in 1801, with the aid of the compound blowpipe. Specific gravity of magnesia is 2.3, and its equivalent is 28.

### *Experimental Illustrations.*

1. The precipitation of magnesia from a solution of its salt, exhibited; also its effects upon vegetable colours.



## SECTION II.

CALCIUM, BARIUM, AND STRONTIUM, THE METALS OF WHICH FORM THE THREE PRE-EMINENTLY ALKALINE EARTHS.

1. These metals are so much alike in their habits that I deem it expedient to treat of them under one name.

Their oxides constitute three of the four earths classed as alkaline, which are pre-eminent in alkaline properties. (1070.) Next to oxygen, silicon, and aluminium,

calcium is probably the most abundant element in the crust of the earth. Barium is comparatively a rare product, and strontium, as an ingredient in our globe, is still more sparingly distributed than barium. Neither exists excepting in combination, and for the most part in the state of oxide in union with an inorganic acid, especially carbonic and sulphuric acid.

*Of the Evolution of Calcium, Barium, and Strontium*

1470. In the last edition of this Compendium, it was mentioned, upon the authority of some of the most improved treatises of chemistry, that Davy had isolated calcium. During the winter of 1838, being engaged in some efforts for obtaining the metal above mentioned, I was induced to re-peruse the original lecture in which the distinguished chemist above named described the results of his attempts to isolate the metals in question.

1471. It should be known, that by Seebeck, and by Berzelius, and Pontin, amalgams had been obtained of calcium, barium, and strontium. From the amalgams of calcium discovered, Davy undertook to distil the mercury; but he frankly declared that he was in nowise certain that he had succeeded in this object. In the case of calcium, his "*most successful*" experiment, "*the tube broke and the metal took fire*" before the process was completed. Subsequently to the date of these facts, as far as I have been enabled to learn, neither Davy nor any other manipulator has succeeded in making a less abortive experiment than that in which he was most successful. This justifies the idea, that there has been some inherent difficulty which could not be overcome by the means to which he resorted. Agreeably to my experience, the weight of sixty grains of mercury, which is the quantity which he alleges himself to have employed, cannot, by the most powerful apparatus, be made to take up a sufficiency of calcium to leave a perceptible quantity of this metal when the mercury is distilled from the aggregate. And I fully concur with him in the opinion, that the temperature requisite to separate mercury from an amalgam, either of calcium, of barium, or of strontium, is higher than glass will bear.\*

\* To enable the reader to judge of the justice of my remarks respecting the experiment advanced by Davy, I will here quote his own language.

"That to obtain a complete decomposition was extremely difficult, since a



1472. Having in my treatise on galvanism, or voltaic electricity, given an engraving and description of my apparatus, and an account of my process for the evolution of the metals in question, I shall here only quote a few words respecting their properties as observed by me.

1473. "Either metal was rapidly oxidized in water, or in any liquid containing it; and afterwards, with tests, gave the appropriate proofs of its presence. They all sank in sulphuric acid; were all brittle and fixed; and, for fusion, required at least a good red-heat. After being kept in naphtha, their effervescence with water was, on the first immersion, much less active. Under such circumstances they reacted, at first, more vivaciously with hydric ether than with water, or even chlorohydric acid; because in these liquids a resinous covering, derived from the naphtha, was not soluble, while to the ether it yielded readily."

### SECTION III.

#### OF LIME, OR CALCIA, THE OXIDE OF CALCIUM.

1474. This oxide exists largely in nature in combination with carbonic acid, forming all the varieties of marble and limestone. Some kinds of white marble, especially that of Carrara, so celebrated on account of its employment in statuary, consist solely of this earth combined with water and carbonic acid, uncontaminated by any

red-heat was required, and that at a red-heat the bases of the earths acted upon the mass, and became oxygenated. When the tube was large in proportion to the quantity of amalgam, the vapour of naphtha furnished oxygen sufficient to destroy a part of the bases; and when a small tube was employed, it was difficult to heat the retort used as a retort sufficiently to drive the whole of the mercury from the base without raising too highly the temperature of the part serving for a receiver so as to burst the tube." "When the quantity of amalgam was about fifty or sixty grains, I found that the tube could not be conveniently less than one-sixth of an inch in diameter, and of the capacity of about half a cubic inch. In consequence of these difficulties, in a multitude of trials I had few successful results; and in no case could I be absolutely certain that there was not a minute portion of mercury still in combination with the metals of the earths."

In a subsequent paragraph the distinguished lecturer adds: "The metal from which I have never been able to examine exposed to air or under naphtha. In the case in which I was enabled to distil the mercury from it to the greatest extent, the retort unfortunately broke while warm, and at the same moment when the air entered, the metal, which had the colour of silver, took fire and burnt, with an intense white light, into quicklime."

\* See Nicholson's Journal, Vol. XXI. for 1808; or, Tilloch's Philosophical Magazine, Vol. XXXIII.

other matter. Hence, if the acid and water be expelled by heat, the lime will remain in a state of purity. Oyster-shells yield very pure lime by heating them to incandescence.

1475. When impure carbonates of lime are exposed to a very high temperature, the matter constituting the impurities is prone to enter into intimate combination with the lime, impairing its causticity, and susceptibility of the slaking process. No doubt this arises from a diminution of affinity for water. The lime of shells is sometimes partially converted into a sulphide, by sulphur derived from the animal matter.

1476. The calcination requires more heat in a crucible, especially if covered, than in an open fire; and if the heat be too sudden, the carbonate may be fused without the expulsion of all the acid, which is afterwards more tenaciously retained. The extrication of the carbonic acid is promoted by a current of steam, or of any other æriform fluid. But steam is preferable, as it is more easily procured, and cannot be productive of impurity. The rationale is, that homogeneous æriform particles interfere with each other more than heterogeneous, which, agreeably to the Daltonian doctrine, to a certain extent oppose no resistance to reciprocal intermixture and penetration.

1477. After the first calcination, Berzelius recommends that the lime be slaked, and again calcined in an open crucible.

1478. *Properties.*—The colour, taste, and smell of this earth, are well exemplified in the best kinds of lime used in building (sometimes called quicklime), which is, strictly speaking, oxide of calcium, isolated from the water and carbonic acid usually united with it as found in nature.

1479. Quicklime has the property of combining, as a base, with water, acting as an acid. (826.) The water becoming, in consequence, consolidated, abandons its latent heat, or caloric of fluidity. Hence great sensible heat is excited, and when the mass undergoing the change is large, ignition occasionally ensues. The lime is by these changes rendered pulverulent, and is said to be slaked. The process is called slaking. The slaked lime thus produced, is by chemists called *hydrate* of lime. (826.) Quicklime is productive of heat, even when triturated with snow.

1480. Water takes up about  $\frac{1}{7}$ th of its weight of this

earth, forming lime-water. On this a pellicle is generated, soon after exposure to the air, by the union of the lime with the carbonic acid, which always exists in the atmosphere.

1481. In lime-water, some metallic oxides are soluble, especially those of lead and mercury. It follows, from the union of acidity and basidity, that in the resulting compounds, the oxides of the metals proper act as acids, while that of calcium acts the part of a base. (629, &c.) The property which lime has of affecting vegetable colours, as an alkali, has already been noticed. (1065, &c.) Though lime is precipitated from the aqueous solution, known as lime-water, by carbonic acid, yet an excess of this acid being supplied, the precipitate is re-dissolved. It is in this way, no doubt, that the water in limestone countries becomes charged with this earth.

1482. The hardening of mortar is ascribed by Berzelius to the affinity between the lime and the silicic acid in the sand. Hence the necessity of this ingredient.

### *Experimental Illustrations.*

1483. Characteristic changes produced in vegetable colours by the solution of the earth in water, called lime-water. A glass of lime-water is not made turbid by air from a bellows, but becomes so on propelling the breath through it. Absorption of carbonic acid by lime-water, shown. Solution of lime by an excess of the acid. Lime precipitated from solutions of its muriate or nitrate, by sulphuric or oxalic acid.

### *Of Peroxide or Bioxide of Calcium.*

1484. Oxygen is absorbed when passed over lime heated to incandescence. By adding lime-water to oxygenated water, acidulated with muriatic acid, Thenard procured crystals of bioxide of calcium. (853, &c.)

### *Of Baryta.*

1485. This earth was named from the Greek βαρύς, heavy; because the minerals containing it are peculiarly heavy, when compared with other earthy substances.

1486. *Preparation.*—To procure baryta, eight parts of the sulphate, finely pulverized, should be intimately mingled with one of charcoal, and afterwards trituated with two parts of resin, sugar, molasses, or wheat flour. The mixture is to be kept at a white heat, in a Hessian crucible, for three-quarters of an hour.

1487. The sulphate of baryta, by being deprived of oxygen, becomes converted into a sulphuret of barium, which yields a nitrate of baryta on the addition of nitric acid. The filtered solution by evaporation yields crystals of the nitrate, which should be decomposed in a porcelain or platinum crucible. This operation is tedious; since the heat cannot be urged beyond a certain degree of intensity, without causing the salt to rise up in a foam, so as to overflow the crucible. If the heat be arrested at a certain stage of the process, Berzelius alleges that a portion of nitrous oxide remains united with the earth, forming a compound which has been mistaken for bioxide ("suroxide") of barium.

1488. Neither the carbonates nor hydrates of baryta, or of strontia are, like those of lime, decomposable per se by heat. The addition of carbonaceous matter enables us to decompose them; as it changes the carbonic acid into carbonic oxide, which has no affinity for the earths, and, therefore, escapes.

1489. *Properties.*—Baryta is acrid, slakes like lime, and is more soluble in water. It is more actively alkaline, both as respects its taste and its action on vegetable colours, than any other earth. It is gray at first, but absorbs water and becomes white. Its aqueous solution is rendered milky by carbonic acid, and, by combining with it, becomes covered with a pellicle of carbonate, when exposed to the atmosphere. From its solution in boiling water, baryta crystallizes on cooling.

1490. Solutions of barium, whether in the state of a hydrate, acetate, nitrate, or chloride, are very useful as tests for sulphuric acid, which, combining with the oxide of barium (baryta), previously existing in the hydrate or nitrate, or formed from the chloride by the decomposition of water, is precipitated by them from any liquid.

1491. Ignited intensely, it absorbs oxygen if exposed to it, and passes to the state of bioxide. This earth is poison-

ous. Its specific gravity is 4, and its equivalent, formed of one atom of barium = 69, and one of oxygen = 8 = 77.

*Experimental Illustrations.*

1492. Baryta, free from water, exhibited; also in crystals. Barytic water rendered milky by the carbonic acid of the breath. Solutions of baryta, and of sulphuric acid, introduced into distinct vessels of pure water, have no effect; but portions mingled in the same vessel produce a cloud. Water, coloured by alkanet, turmeric, &c., changed by baryta, as by an alkali.

*Of Strontia.*

1493. This earth is very analogous to baryta in its properties and composition. It is distinguished from baryta, by the red colour which its solutions communicate to flame, by its crystallization, and by its being more soluble in boiling water and less so in cold. Excepting baryta, it is more actively alkaline than any other earth, both as respects taste and its action on vegetable colours.

1494. Strontia water is not like that of baryta precipitated by a dilute solution of the sulphate of potash, or that of soda, and when added to a solution of bichromate of lead its power as a precipitant is inferior.

1495. Strontia may be obtained from the carbonate or sulphate, by a process in every respect similar to that which has been described as the means of procuring baryta.

1496. The equivalent of this earth is 52.

*Experimental Illustrations.*

1497. Turmeric, alkanet, and red cabbage, changed by strontia-water, as by alkalies. Red colour of the flame of alcohol, containing strontia, shown. Effects of the aqueous solutions of the alkaline earths on a solution of bichromate of lead.

*Of the Peroxides or Bioxides of Barium and Strontium.*

1498. When the protoxides of barium and strontium

are heated in contact with oxygen gas, they absorb it, and are converted into bioxides. When an aqueous solution of these earths is added to oxygenated water, the bioxides of their metallic radicals are precipitated in a crystalline form.

1499. It was by means of a bioxide of barium thus procured, that Thenard was enabled to obtain *oxygenated water*. (853.) The bioxide of barium was dissolved in chlorohydric acid. By adding sulphuric acid, sulphate of baryta was precipitated, in which half of the oxygen of the bioxide was retained, the other half being left in combination with the water of the solvent. This operation being repeated several times, the liquid became more and more surcharged with oxygen. Afterwards, the chlorine of the acid was precipitated by sulphate of silver, and the sulphuric acid, thus introduced, by baryta. Finally, the bioxide being less susceptible of vaporization than water, this liquid was removed by evaporation in vacuo over sulphuric acid. (399.) Thus isolated, the oxygenated water was ascertained to deserve the appellation of bioxide, being found to hold two equivalents of oxygen for one of hydrogen.

OF THE METALS OF THE FIXED ALKALIES, OR ALKALIFI-  
ABLE METALS, POTASSIUM, SODIUM, AND LITHIUM.

### SECTION I.

#### OF POTASSIUM.

1500. The discovery of potassium and sodium was made by Sir Humphry Davy, in 1807, by exposing their oxides, potash, and soda, to the divellent influence of the Voltaic current. These metals were afterwards obtained more copiously, by subjecting the alkalies, in contact with iron in a divided state, to intense heat in a luted gun barrel. Latterly, they have been obtained, with still greater facility, by heating the carbonates intensely, while intermingled with charcoal.\*

\* In Brunner's process, bitartrate of potash, or carbonized cream of tartar, which consists of carbonate of potash intimately intermingled with the residual carbon of the decomposed tartaric acid, is subjected to intense heat in a luted iron mercury bottle, some coarsely powdered charcoal being added. The potassium was conveyed into a copper vessel containing naphtha as it came over from the bottle. For this vessel, I have substituted an iron tube, which becomes finally full of the metal and a carbo-

1. The alkaline metal, whether potassium or sodium, volatile at any temperature above redness, is extricated in the state of vapour, and condensed in a part of the apparatus where the heat is below redness.

2. *Properties.*—Potassium, when newly cut, strongly resembles silver in appearance. It is malleable, and so at ordinary temperatures, as to be moulded between the fingers like wax. When cooled to  $32^{\circ}$ , it becomes brittle and exhibits, when broken, a crystalline fracture. It melts at  $106^{\circ}$ , and is converted into vapour when heated above redness. When exposed to the air at the ordinary temperature, it absorbs oxygen rapidly, and is converted into potash. This absorption is sometimes so rapid, especially when aided by friction, as to cause the oxidation of the potassium. I once lost half an ounce of potassium, in consequence of attempting to extricate it from the containing bottle by a file; it took fire, and was entirely oxidized. The affinity of this metal for oxygen is so strong, that, when thrown upon water or ice, it reacts with the oxygen; while the hydrogen takes up a small portion of the potassium, and burns with a beautiful blue-coloured flame. Potassium is lighter than water, its specific gravity being only 0.86. It is a good conductor of heat and electricity. Its atomic weight is 40.



## SECTION II.

### OF SODIUM.

1. *Properties.*—Sodium resembles potassium in its appearance, and in many of its properties. It retains its

lustre, which sublimates during the operation. The tube is then removed, and the nearest the bottle screwed into a tapering tube, while the other orifice is closed with a cap, into which it fastens by screwing. The tube is then placed vertically over the furnace, through the bottom of which the tapering tube extends so as to be out of the heat. Under the orifice of this tube, a vessel may be placed containing naphtha, to receive the potassium as it descends in globules, after fusion of the metal from the state of vapour. The last portions are not evolved before the furnace reaches a white heat. The principal source of disappointment in the latter process, is the failure of the luting. When this happens, the metal is soon burnt through. I have found it advantageous to secure the iron employed in this process, while supported vertically in the furnace, by a stout rod of the same metal, the whole resting upon an iron disk supported by bricks and a coal-pan earth.

By these means, I procured last winter, at one operation, more than six ounces of

softness and malleability when cooled to  $32^{\circ}$ . A globule of sodium, thrown upon water, swims to and fro on the surface with great rapidity, absorbing oxygen, and evolving hydrogen from the water; yet no inflammation ensues. This is probably owing to the rapidity of its motion, which, by bringing it in contact with successive portions of water, keeps the temperature below that which is necessary to combustion; since, when the water is thickened with a little gum, which tends to impede the motion of the globule, sodium burns with a brilliant yellow flame. The presence of an acid produces the same result. The affinity of sodium for oxygen, does not appear to be so strong as that of potassium; since, according to Thenard, it is not oxidized when exposed to dry atmospheric air, or oxygen. It melts at  $194^{\circ}$ , and for volatilization, requires a higher temperature than potassium.

1504. Sodium forms a number of alloys with potassium; one of these remains fluid at  $32^{\circ}$ , and is lighter than naphtha. The specific gravity of sodium is 0.97223. It is a good conductor of heat and electricity. Its atomic weight is 24.

### *Experimental Illustrations.*

1505. The inflammation of potassium and sodium upon water and ice, exhibited; also the regeneration of the alkali, demonstrated by the usual tests. The decomposition of potash, by iron card-teeth, heated to incandescence. Apparatus for its evolution, exhibited.

### *Of Potash or Potassa, and Soda, the Protoxides of Potassium and Sodium.*

1506. A ley, obtained by the lixiviation of the ashes of inland plants, especially wood, when boiled down, yields the potash of commerce. Potashes ignited so as to destroy vegetable colouring matter and other impurities, again dissolved, and boiled to dryness, form pearlsh. Pearlsh, dissolved in water, boiled with lime to remove the carbonic acid, filtered, and boiled down to the consistency of moist sugar, dissolved in alcohol, and boiled down gradually, and, lastly, fused at a red-heat in a silver vessel, forms the potash, or, more strictly, the *hydrate* of potash of chemists. If, as soon as the alcohol has escaped, the residual mass



be refrigerated, it crystallizes. After fusion at a red-heat, the alkali contains about 20 per cent. of water, existing in it as an acid, and of which, per se, it cannot be deprived by heat.

1507. Pure carbonate of potash may be procured from bitartrate of potash, whether carbonized by heat, or deflagrated with pure nitre, by subjecting the residue to water, and the resulting solution to heat, to vaporize the solvent.

1508. To obtain pure potash, or in other words, to remove carbonic acid from the alkali of a carbonate, Berzelius advises the addition of one and a half parts, by weight, of pure hydrate of lime, to one part of a pure carbonate, obtained as abovementioned, dissolved in a cauldron, and kept boiling. The lime is not to be added at once, but gradually; as without this precaution, the resulting carbonate of lime retains, like a sponge, a great part of the alkali. The liquid is to be tested by an acid or by lime-water, until it ceases to indicate the presence of carbonic acid. After this, it may either be kept in a liquid state, or evaporated till it crystallizes, and preserved in crystals; or being ignited till it becomes fused, and poured out on a slab, or into moulds, it may be preserved in the state of hydrate.

1509. I have used for the purpose last mentioned, the moulds usually employed for casting musket balls. The spherical form presenting the least surface in proportion to the mass, is favourable to the preservation of a substance liable to be deteriorated by contact with the atmosphere.

1510. The crystals of potash, thus procured, are always free from carbonic acid, and if derived from a pure carbonate, excepting water, may constitute pure potash. But when pearlash is the carbonate employed, alcohol must be resorted to, after the caustic ley has been evaporated to the consistency of moist sugar, in order to get rid of the impurities. This liquid combines with the pure potash, while a portion of water contained in, or formed from, the alcohol, separates from it in union with the impurities.

1511. Soda is obtained from the ashes of certain plants which grow on the sea-shore, as potash is by the incineration of those which grow inland. It is procured also from chloride of sodium, and sulphate of soda.

1512. Soda is purified, and procured in the state of hy-

drate, or in crystals, by a process analogous to that above described for its kindred alkali.

1513. *Properties of Potash and Soda.*—Potash and soda are of a grayish-white colour, and, in common with other alkalies, have a peculiar taste. They render tincture of turmeric brown, syrup of violets green, and alkanet blue. Colours changed by acids, are restored by them. They are the opposites of, and antidotes to, acids, and capable of forming with them neutral compounds, or, in other words, such as are neither acid or alkaline. They are incorrectly said to render vegetable blues green, as if this were universally true. Alkanet is made blue by them, while neither litmus nor indigo is rendered green. (1065, &c.)

1514. Although potash is more soluble than soda, and is deliquescent, while soda effloresces; yet the salts of soda are more soluble than those of potash. Both cauterize the flesh. Potash is the more active. Common caustic is an impure hydrate of this alkali.

1515. Crystallized potash contains four atoms of water to one of the oxide, of which three only can be expelled by heat. After fusion it may be called, however paradoxical it may seem, an anhydrous hydrate, though not an anhydrous oxide. Both potash and soda fuse when subjected to a red-heat. The atomic weight of potash is 48, that of soda, 32. The hydrate of potash consists of one atom of alkali, and one of water.

1516. Potash may be distinguished from soda, by its forming salts nearly insoluble in water with tartaric, or oxychloric acid; while those formed by soda with the same acids are soluble. Chloroplatinic acid causes a yellow precipitate with potash, but not with soda.

#### *Experimental Illustrations.*

1517. Characteristic changes produced in vegetable infusions, as in previous illustrations. (1075.)

1518. To a saturated solution of potash and soda, or their carbonates, a saturated solution of tartaric acid being added in excess, crystals are yielded by the potash only. Into different salts of the two alkalies in solution, chloroplatinic acid being poured, a yellow precipitate distinguishes the potash.

*Of the Peroxides and Suboxides of Potassium and Sodium.*

519. *Peroxide of potassium* is produced by the combustion of potassium in a state of silver in oxygen gas, in which case the metal acquires three times as much oxygen as it holds in the state of potash. The peroxide is also obtained when nitre intensely heated, or when potassium is deflagrated with nitre.

1520. Two parts of sulphate of potash, ignited intensely with one of lampblack, give a pyrophorus which takes fire spontaneously with scintillations in the air. This arises, no doubt, from the extreme state of division in which carbon, potassium, and sulphur exist in the residual mass.

1521. *The peroxide of potassium* is of a greenish-yellow colour, and possesses most of the properties of the protoxide, excepting that of acting as a base. When brought in contact with water or acids, it is decomposed into potash and oxygen.

1522. *The peroxide of sodium* is of a greenish-yellow colour also, and, in its properties, is analogous to the peroxide of potassium, except that at a high temperature it abandons part of its oxygen, and is converted into protoxide. It cannot, therefore, be obtained by burning sodium in an excess of oxygen; since the heat produced by the combustion, would decompose the peroxide, if already formed. In order to procure it, it is necessary to heat soda in contact with oxygen. The peroxide of sodium contains one and a half atoms of oxygen, united to one of metal.

1523. Berzelius mentions that suboxide of potassium may be obtained by heating a metal in a quantity of oxygen inadequate for its saturation; also by exposing to a temperature of about 40° F., a mixture of hydrate of potash and potassium, in equivalent proportions; in which case the metal is oxidized at the expense of the combined water, the hydrogen escaping. The anhydrous protoxide may be obtained in the same manner, by heating potassium with a greater quantity of the hydrate. Turner observes, however, that the suboxide of potassium is generally regarded by chemists as nothing more than a mixture of potassium and potash.

1524. According to Berzelius, a suboxide of sodium may be obtained by the same means as the suboxide of potassium, substituting the one metal for the other. The same uncertainty, however, prevails with regard to it, as with regard to the suboxide of potassium.

1525. When potassium or sodium is heated in ammonia, it combines with nitrogen and liberates hydrogen, and the resulting nituret absorbs ammonia; so that we have combination of two binary compounds of nitrogen, which may possess, to a small extent, the relation of acid and base. There are, however, no phenomena in chemistry which are more anomalous than those which are associated with the production and evolution of this compound. Nevertheless, as its nature is unintelligible even to adepts, I shall not present the details here.

1526. I hinted, when entering upon the subject of nitrogen, that it would be seen by and by, that it was not destitute of pretensions to a place in the basacigenous class. It was in reference to the phenomena above alluded to, that I made that remark.

1527. If nitrogen form the common ingredient in two compounds, one electro-negative, the other electro-positive, which combine to form a third, it fulfils the condition of a body producing both an acid and a base, and is of course a basacigenous body. Yet it has already been pointed out that there is no class, of which some of its members do not display properties which might cause them to be placed in another class.

*Of Phosphuret of Potassium.*

1528. Phosphorus and potassium, heated together in nitrogen or hydrogen gas, combine with the phenomena of combustion. In phosphuretted hydrogen, potassium combines with phosphorus, and liberating the hydrogen.

1529. This phosphuret decomposes water, but, according to Berzelius, the gas evolved does not inflame spontaneously.

*Of the Compounds of Potassium with Carbon, Boron, and Silicon.*

1530. The black matter which remains after the distillation of potassium, as obtained by Brunner's process, is alleged by Berzelius to be a *percarburet of potassium*. When moistened it inflames, no doubt by decomposing water, and evolving potassium hydrogen. The black matter which obstructs the tube used in the evolution of potassium by the process above mentioned, is also held to be a carburet. (1501.)

1531. These carburets I have found useful in purifying naphtha, by its distillation through them. After undergoing this ordeal, potassium may be kept in it with less ap-

pearance of reaction. I am under the impression that the carbon which remains in the iron bottle, is imbued with potassium, possibly in a state of chemical union. This may be used likewise for the purification of naphtha.

1532. It appears that, during the reduction of boric acid by potassium, a boruret is formed; since a portion of the mass evolves a gas on being moistened, which has not the smell of pure hydrogen. It is probably boruretted hydrogen.

1533. A *siliciuret of potassium* is obtained during the decomposition of fluosilicic acid gas. A portion of the liberated silicon, combining with potassium, forms the compound in question. This, on being moistened, gives off hydrogen, which has a peculiar odour resembling that of phosphuretted hydrogen. The analogy between these results and those mentioned in reference to boron, is obvious.

### SECTION III.

#### OF LITHIUM.

1534. A fixed alkali was discovered, in 1818, by Mr. Arfwedson, to exist in small proportion, as an ingredient in a mineral called petalite. He afterwards discovered it in two other minerals, called spodumene and lepidolite. Allusion to this alkali, and the origin of its name, was made under the head of Ammonia. (1081.)

1535. By the influence of the Voltaic pile, decided indications have been obtained of the existence, in lithia, of a metallic radical. To this the name of lithium has been given. Lithium resembles sodium in appearance. Its atomic weight is 6.

#### *Of Lithia.*

1536. Lithia, known only in the state of hydrate, is white, caustic, and has all the attributes of an alkali. When lithia, whether in the state of carbonate or uncombined, is heated in contact with platinum, the metal is attacked, and a compound is formed, which, according to Thenard, probably consists of the oxide of platinum, united to the oxide of lithium, and must of course be a platinate of lithia. Lithia is composed of one atom of lithium, equivalent 6, and one atom of oxygen, equivalent 8 = 14.

1537. Lithia is less soluble in water or alcohol than soda or potash. Its carbonate is less soluble in water than the carbonates of those alkalies. The chloride of lithium is deliquescent, and soluble in alcohol, the phosphate of lithia is insoluble in water; in which respects these compounds differ from the corresponding combinations, formed by the other fixed alkalies, or their radicals.

#### *Of the Reaction of Chlorine, Bromine, Iodine, Fluorine, and Cyanogen, with the Metals of the Earths and Alkalies.*

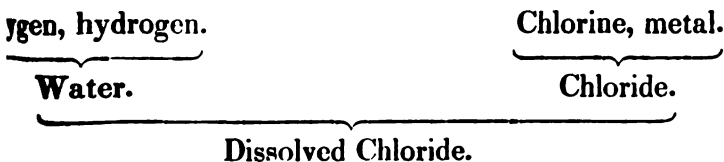
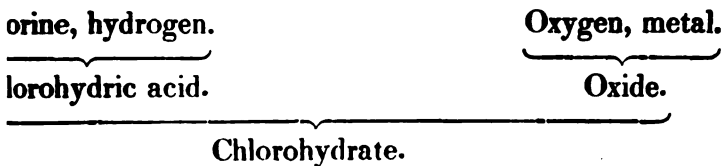
1538. In a former edition of this work, it was mentioned that for aluminium, glucinium, yttrium, thorium, and magnesium, chlorine has not sufficient affinity to expel the oxygen from their oxides; and that it was only in the state of oxide that they could be subjected to the gas-

as been already stated, that Oersted ingeniously contrived to enable chlorine to combine with aluminium, by co-operating affinity of intermingled carbon for the oxygen with which, in the state of earth, this metal is associated: also, that a similar process had been successfully employed to obtain the chlorides of glucinum, yttrium, cerium, and magnesium. The most important consideration, associated with the existence of these chlorides, is their susceptibility of decomposition by potassium, and the consequent isolation of their metallic radicals.

539. When the oxides of calcium, barium, strontium, potassium, sodium, and lithium are heated in chlorine, these oxides are converted into chlorides, the oxygen being displaced. Potassium and sodium burn actively in chlorine, and it appears probable that any of the metals of the alkalis or alkaline earths may, with heat, if not without, be directly combined with any of the halogen bodies. The same combinations may be obtained in the wet way by double affinity, on presenting their oxides to the acids generated by these bodies with hydrogen.

540. The chlorides of the metals of the alkalis, and the alkaline earths, are all soluble, and some of them caustic. When in solution, they contain the same elements as if they were chlorohydrates of oxybases; and are therefore, considered as such by some chemists.

541. The difference between a chloride in solution and a chlorohydrate, is rendered evident by setting down the ingredients agreeably to both suppositions, as follows:—



1542. The soluble chlorides produce white precipitates in solutions of silver, lead, or black oxide of mercury. They do not deflagrate with charcoal, nor do they, like sulphates, after being heated with it, yield the odour of sulphuretted hydrogen on being moistened.

1543. The soluble chlorides of the metals of the alkaline earths and alkalies, excepting that of magnesium, are, by heat, converted into anhydrous chlorides, easily detected by the fumes which they give with sulphuric acid.

1544. Bromine, like chlorine, when heated with any of the fixed alkalies, or alkaline earths, except magnesia, displaces the oxygen and combines with the metallic radical. Like chlorine also, it does not, per se, produce this effect either with magnesia or the earths proper.

1545. The affinities of iodine are, in most cases, less energetic than those of chlorine or bromine. Potash and soda are the only oxides of the metals of the earths and alkalies, from which iodine can, with the assistance of heat, expel the oxygen, in order to combine with their metals.

1546. The bromides and iodides, when combined with water, may, like the chlorides, be regarded either as in a state of solution, or as bromohydrates and iodohydrates. The bromides may be recognised by the red vapours which arise, when they are heated in a tube with the bisulphate of potash. Similar vapours would be given out by the nitrites, if treated in the same way; but the bromides may be distinguished from those salts, by their not deflagrating when thrown on incandescent coals.

1547. An iodide may be detected by dropping a portion into sulphuric acid, heated nearly to the point of ebullition. (738.) By these means iodine, if present, will be made apparent in the form of a violet vapour. Iodine is also displaced from its combinations by chlorine; and, when these, previously to the addition of chlorine, are mingled with a paste made of starch, a blue colour is produced. It is alleged that sea salt sometimes contains a quantity of iodine adequate to produce this result.

1548. Berzelius states that, when potassium is heated in cyanogen, it is converted into a cyanide; also that the habitudes of sodium are in this respect similar. It is probable that the same result would ensue with all the metals

alkalies and alkaline earths. Cyanogen is usually formed by the reaction of potash with animal matter, which oxidizes the alkali, and at the same time furnishes the elements of cyanogen, which, in consequence, immediately unite with each other and with the metal, forming a cyanide of potassium.

1. When the cyanoferrite of potassium (ferrocyanide of potash) is intensely heated, the cyanoferric acid is decomposed. The cyanide of potassium remains mingled with the carburet of iron, and may be extricated by solution, followed by evaporation, and crystallization. Subjecting the cyanoferrite of sodium to a similar process, the cyanide of sodium may be obtained. (1299, &c.)

2. The cyanides may be detected by their power of turning a blue colour with solutions of the peroxide of iron, or also by evolving the odour of peach blossoms, when added to chlorohydric acid.

3. It is highly probable that the reaction of fluorine with the metals of the earths and alkalies, will prove to be analogous to that of chlorine. The fluorides, however, differ much from the chlorides in solubility. Some varieties of the fluoride of calcium constitute Derbyshire spar, while the chloride of calcium is a deliquescent salt.

4. The presence of fluorine in a mineral may, in a variety of instances, be detected by the following process. A small portion of it be pulverized, and subjected to the action of about twice its weight of concentrated sulphuric acid in a leaden, silver, or platinum cup. Let this cup be covered by a glass plate, coated with beeswax, through which some letters have been traced so as to denude the glass surface. After exposure for half an hour, aided by much heat as can be used without melting the wax, the glass should be relieved from its coating and examined. If the portions of the vitreous surface, exposed to the acid, prove to be so corroded as to render the characters traced through the wax distinguishable, the presence of fluorine may be inferred.

5. Berzelius informs us that when this principle is in contact with silicon, it will not act on glass. Hence it follows that the mineral, suspected of containing fluoric acid, should be subjected to the flame of the blow-pipe at one end of a glass tube, of which both ends are closed so that the fumes produced may be impelled by the

blast through the tube from one orifice towards the other. By these means, milky spots will appear on the glass, in consequence of the condensation of water containing fluo-silicic acid, if this be an ingredient in the mineral.

*Of the Reaction of Sulphur, Selenium, and Tellurium, with the Metals of the Earths and Alkalies.*

1554. Sulphur unites with all the metals of the alkalies and alkaline earths, so far as the experiment has been tried, whether presented to them in the metallic state, or in that of oxide. Its power of reducing their oxides is greater than that of any other basacigen body; as when present in excess, it acts by its affinity for the oxygen and the metal. (523, &c.) The affinity of the halogen bodies for oxygen, is so inferior to that of sulphur, that when oxygen is expelled from oxides by one portion of them, it does not combine with another, however great the excess in which they may be present.

1555. Sulphides (sulphurets) are also formed by deoxidizing the sulphates by carbon or hydrogen with the aid of heat, (1436, 1437,) by boiling in water equivalent weights of sulphur and the earth or alkali to be combined; or by passing sulphydric acid into water, holding the oxide in solution or suspension. When this is done under favourable circumstances, the metal is converted into a sulphobase by the sulphur of one portion of the acid; while the compound thus formed unites with another portion of the acid, forming a sulphosalt, denominated a *sulphydrate*. This view of the subject we owe to Berzelius, who has shown that sulphur, selenium, and tellurium, all have the property of forming acids with one set of radicals, and bases with another; and that the sulphacids and sulphobases thus formed, are capable, like oxacids and oxybases, of forming compounds which he considers as sulphosalts, or salts in which sulphur performs a part analogous to that which oxygen performs in oxysalts, such as the sulphate or nitrate of potash.

1556. Formerly it was supposed that, when absorbed by an alkaline solution, sulphydric acid (sulphuretted hydrogen) combined with the oxybase, forming what was called a hydrosulphuret. It was also supposed that a sulphide of an alkalifiable metal, by solution in water, would be converted into an oxybase by the oxygen of the water; while



the hydrogen, with a double proportion of sulphur, forming bisulphuretted hydrogen, would combine with the oxybase.

1557. Through the sagacity and industry of Berzelius, much knowledge has of late years been acquired respecting the combinations of sulphur with the alkaline metals. He mentions seven compounds, in which, supposing the quantity of the potassium in each to be the same, the quantities of the sulphur are severally 1, 2, 3,  $3\frac{1}{2}$ , 4,  $4\frac{1}{2}$ , 5.

1558. To remember the details respecting the preparation and characteristics of these sulphides, would be too great a burthen for the memory of those who are not so situated as to take a particular interest in them.

1559. Sulphides of the metals of the earths and alkalies, on being moistened with water, evolve sulphydric acid, and produce this result still more actively on being subjected to chlorohydric acid.

1560. The selenides of the metals of the earths and alkalies may, in most cases, be produced by heating the metal with selenium. The selenides of these metals bear a great resemblance to the sulphides, and when heated are reduced to the metallic state, producing the smell of horse-radish.

1561. The tellurides are but little known, and, except so far as they act as telluracids or telluribases, so as to give pretensions to tellurium to be placed among the basacigen elements, they are uninteresting.

### *Experimental Illustrations.*

1562. Sulphides in solution exhibited. Earths precipitated by acids.

### OF METALS PROPER.

1563. The metals included under this head, are *gold, platinum, silver, mercury, copper, lead, tin, bismuth, iron, zinc, arsenic, antimony, palladium, rhodium, iridium, osmium, nickel, cadmium, chromium, cobalt, columbium, manganese, molybdenum, titanium, tungsten, uranium, cerium, and vanadium.*

## SECTION I.

## OF GOLD.

1564. Gold is usually found in nature nearly pure. It is not liable, like other metals, to be disguised by a union with oxygen or sulphur. The precipitate obtained from a solution of gold coin in aqua regia, by the green sulphate of iron, is pure gold. This metal is also purified by exposure to heat and air, or by nitric acid, by which means baser metals are oxidized; as in the processes of cupellation and parting.

1565. From the sands, or ores, in which they exist naturally, minute portions of gold are collected by trituration with mercury, with which they amalgamate. The mercury is distilled from the amalgam thus obtained, by means of an iron alembic.

1566. *Properties.*—The specific gravity of gold is 19.3, and its equivalent 200. Its colour and lustre are too well known to need description. It is the most malleable and ductile metal, and suffers the least by exposure to air and moisture. Gold leaf, which is about 1000 times thinner than printing paper, retains its lustre in the air. Gold leaf transmits a greenish light, but it is questionable whether it be truly translucent. Placed on glass, and viewed by transmitted light, it appears like a retina. It is erroneously spoken of as a continuous superficies.

1567. Gold fuses at a low white-heat, but requires the temperature produced by the compound blowpipe, by galvanism, or by the explosive power of electricity, to volatilize or oxidize it. Its not being liable to tarnish by exposure, is due to the weakness of its affinity for oxygen or sulphur.

1568. When a solution of chloride of gold is mixed with sulphuric ether, the ether takes the metal from the chlorine, retaining it in solution. If iron or steel be moistened with this ethereal liquid, it is productive of a slight gilding.

1569. Phosphorus, carbon, and the baser metals, also hydrogen gas and its compounds, by a superior affinity for oxygen or chlorine, precipitate gold from the solution of its chloride in the metallic form.

1570. The abstraction of oxygen precipitates gold, by liberating the hydrogen of water. The hydrogen thus liberated, takes chlorine from gold, forming of course chlorohydric acid, which has no affinity for this metal, unless in the state of chloride. As oxygen is necessary to the base of an oxy-salt, so chlorine is indispensable to the constitution of a chloro-salt.

1571. The union of gold with mercury, was adduced as an exemplification of simple chemical combination. (515.) The compound thus formed, when the ingredients are in due proportion, is of great use as the mean of that kind of gilding which is the most firm and durable. The affinity between the mercury and copper, renders it easy to coat with the amalgam the surface of any mass formed of this metal. Subsequently, the mercury may be driven off by heat, leaving a pellicle of gold upon the cupreous surface, which only requires burnishing, in order to display the colour and brilliancy of gold.

1572. With arsenic, gold combines energetically, absorbing this metal in the form of vapour, at a red-heat, without changing colour. Gold loses its malleability by acquiring  $\frac{1}{80}$ th of its weight of arsenic. Probably gold may be united with all the metals. Phosphorus forms with it a brittle compound.

The affinity between chlorine and gold is pre-eminently energetic. In solution, whether the metal be heated in the gas, or presented in aqueous solution, or in aqua regia, which is essentially a solution of chlorine in water. Aqua regia is produced by the mixture of chlorohydric acid. It ought not, however, to be considered as a combination.

As soon as the mixture is effected, a decomposition of both of the elements commences.

One atom of nitric acid, by yielding three out of its five atoms of oxygen (957,) can take all the hydrogen from three atoms of chlorine. (874.) In this case, three atoms of chlorine and one of nitric oxide are emancipated. The acids employed be concentrated, both the nitric oxide and the chlorine evolved; but if there be a sufficiency of water, the chlorine remains in solution with it, forming a more concentrated aqueous solution of chlorine than otherwise be made. Excepting that it contains chlorine in a higher degree of concentration, which of course enables it to act with more energy, aqua regia does not differ, in its solvent powers, from a solution of chlorine in water. It cannot properly be considered as a distinct acid; it only acts by imparting chlorine, being incapable, as an aggregate, of entering into combination.

The name of aqua regia, or royal water, was given to this solvent, on account of its property of dissolving gold, the alleged king of metals. Since the promulgation of the French nomenclature, it has been called *nitrochloric acid*; but as this conveys a false idea of its nature, I would prefer its old name, aqua regia, or, if a new name be necessary, I suggest that of *nitrohydrous chlorine*. Latterly Gay-Lussac has called that *iodic acid* is a solvent of gold; and by Mitscherlich, the same is ascribed to selenic acid. When boiled with three parts of sulphur, and one of potash, one part of gold is dissolved as an ingredient in a soluble salt. (1541.)

#### *Of the Compounds of Gold with Oxygen.*

By subjecting a protochloride of gold to a solution of caustic potash, oxide of gold, the chlorine and oxygen exchange places; so that a protoxide of gold, and chloride of potassium result. The trioxide of gold is obtained by digesting an aqueous solution of the bichloride with magnesia in slight excess. This oxide, which is capable of acting both as an oxidant and as an oxybase, in this instance acting in its basic capacity, combines with the magnesia, and constitutes an aurate, of which the greater part precipitates, while the remainder continues in solution. The precipitate could be washed with water until it ceases to acquire a yellow colour by the addition of chlorohydric acid. It should then be digested with nitric acid, which, with the magnesia, and thus isolates the trioxide. If the nitric acid employed be concentrated, we obtain the trioxide in an anhydrous state, and of a brown colour; but if dilute, as a yellowish-red hydrate.

The protoxide consists of one atom of gold and one of oxygen, the trioxide, of gold and three of oxygen. Hence, agreeably to the example of Thenard, we use it as a trioxide. (756.) Acting as a base, this oxide combines with nitric acid. It is precipitated from these combinations by water, which acts, in this case, as an oxybase of hydrogen. (826.)

As an oxidant, trioxide of gold unites with all the alkalies and alkaline earths. In the case of ammonia, a compound which explodes by percussion, has long been known under the name of fulminating gold. Berzelius alleges that there are two kinds, containing an excess of ammonia, detonates more powerfully; the other, with a lesser quantity of the alkali, contains chloride of gold, by which it is enfeebled.

A precipitate, of a beautiful purple colour, may be obtained either by mixing solutions of the chlorides of tin and gold; or by immersing an ingot of tin, in a solution of chloride of gold, containing some free chlorohydric acid. This precipitate the name of purple powder of Cassius has been given. I infer from account of this compound, given by Berzelius, that it consists of gold, tin,

hydrogen, and oxygen. Respecting the mode of combination there is some obscurity.

1580. In consequence of this property of producing the purple of Cassius, tin, whether in the metallic state or that of dissolved protochloride, is the best test for gold.

1581. Berzelius does not consider the purple powder into which gold is reduced by successive electric discharges, as any thing more than metallic gold in a state of minute division.

*Of the Compounds of Gold with the Halogen Bodies.*

1582. The *protochloride of gold* is obtained by exposing the trichloride to a gentle heat, which drives off two atoms of chlorine, leaving the gold in combination with the remainder. If the heat be carried too far, it is apt to decompose the protochloride into metallic gold and chlorine. On this account it is better to stop the operation before the trichloride is entirely decomposed, and to wash the resulting mass with water, which removes the trichloride, and leaves the protochloride, which is insoluble in that fluid when cold. A solution of the trichloride of gold is obtained when gold is dissolved in aqua regia, any excess of chlorohydric acid is expelled by heat. It is of a pale yellow colour, and has an astringent and disagreeable taste. This chloride combines as an acid with the chlorides of the alkaline metals, forming chloroaurates. Hence I consider this as entitled to the appellation of *chloroauric acid*. The trichloride of gold, as its name implies, is composed of one atom of gold, and three atoms of chlorine.

1583. Bromine forms with gold a tribromide, which corresponds in composition and chemical properties with the trichloride of the same metal. The iodide of gold agrees, in composition and chemical relations, with the protochloride of gold. The cyanide of gold appears to act as an acid.

*Of the Compounds of Gold with Sulphur.*

1584. Gold forms with sulphur a protosulphide and a trisulphide. The protosulphide is formed by passing a current of sulphydric acid gas through a boiling solution of the trichloride. It is of a deep brown colour, and is decomposed by heat into metallic gold and sulphur. The trisulphide may be precipitated by passing a current of sulphydric acid into a dilute solution of the trichloride, or by adding an acid to a solution of the sulphurate of potassium. The trisulphide is of a deep yellow colour, and is decomposed by heat. With sulphobases it acts as an acid, but with the more powerful sulphacids as a base.

*Experimental Illustrations.*

1585. Some gold leaf is placed in two glass vessels. Nitric acid being poured into one, and chlorohydric acid into the other, the gold is not acted upon; but when the contents of the two vessels are united, the gold disappears.

1586. Gold, dissolved by aqua regia, and precipitated by sulphate of iron, or by chloride of tin. A cylinder of phosphorus, immersed in a solution of the metal, acquires the appearance of a cylinder of gold. Separation of gold from its solution by ether. Effects of the ethereal solution exhibited. Action of mercury on gold leaf.

## SECTION II.

## OF PLATINUM.

This metal is found in South America, and in Russia, in an im-  
mular form, known as the native grains of platinum. In addition  
etal, the native grains contain several other metallic substances in  
combination or mixture. The aggregate thus described is, for the  
t, soluble in aqua regia; the habitudes of platinum, in this respect,  
s in others, being more analogous to those of gold than any other  
nature. On adding to a solution of the native grains of platinum, in  
gia, a solution of sal-ammoniac, an orange-yellow precipitates, but  
ible in water, is obtained. This being carefully washed and desic-  
d finally exposed to a red-heat, in a platina, porcelain, or black  
ible, the metal is isolated in a mass so porous, as to have received  
of platina sponge, from its resemblance in structure to the well  
ubstance to which this name belongs. By extreme mechanical  
the platina sponge is so far consolidated that by intense heat and  
ag it is welded into a perfectly tenacious mass, having, in a high  
ll the attributes of a noble metal. (1404.)

I have lately been enabled, by an improvement in my hydro-oxy-  
pipe, to fuse twenty-five ounces of platinum into a malleable mass.  
al thus obtained, is less liable to flaws than that produced by the  
process above described. My process is especially important as  
us to unite old platina ware, or clippings, into malleable masses of  
nt dimensions, without re-solution in aqua regia. The necessity of  
is last mentioned course, reduces platina in that state, to a value  
than  $\frac{1}{4}$  higher than that of the native grains. (394.)

According to Berzelius, platinum, as obtained by the process  
ntioned, is alloyed with iridium, and inferior to the pure metal in  
illiancy, ductility, and malleability; while at the same time it is  
and more suitable for the purposes for which it is usually em-  
It may be obtained pure, by precipitating chloroplatinic acid  
queous solution by chloride of potassium, igniting the precipitate,  
ng it, and precipitating again by sal-ammoniac; and lastly, by re-  
e precipitate by ignition to the spongy form, from which by pres-  
the welding process, it may be made coherent and malleable, as  
vementioned process for obtaining the metal.

**Properties.**—The colour of this metal, as ordinarily obtained, is  
ate between that of silver and steel; but when pure, as above  
resembles silver both in colour and softness, more than when  
with iridium. Its specific gravity is 21.53. A cubic inch of it  
ore than three-fourths of a pound. It is nearly twice as heavy as lead,  
heaviest body known. It is less ductile and malleable than gold,  
r and more tenacious; though, in these respects, inferior to iron.  
, it is susceptible of being hammered and welded at a white-heat.  
ther be oxidized nor melted by the highest temperatures of the air-  
x forge. It was first fused in a focus of the solar rays, afterwards  
of a stream of oxygen gas on ignited charcoal, but much more  
the compound blowpipe, under which it was first oxidized and dis-  
y heat. It fuses and burns easily in the Voltaic circuit, and is

dispersed and oxidized by mechanical electricity. It is one of the worst conductors of heat among metals.

1591. In its habitudes with oxygen, chlorine, and the acids, it is analogous to gold, being, like that metal, detected by protochloride of tin, which produces with it a claret colour. It unites so energetically with tin at a red-heat, as to occasion the phenomena of combustion. (348.) When in a divided state, as obtained by igniting the chloroplatinate of ammonium, it amalgamates with mercury by trituration.

1592. Platinum combines with boron, silicon, and phosphorus. On account of its infusibility at the highest temperatures produced by the air-furnace, or forge, and its insusceptibility of being corroded by the acids usually employed in chemical processes, it is much used by chemists for crucibles, evaporating vessels, and spoons; also in experiments in which Voltaic series are resorted to as a means of decomposition. I employ it in my galvanic ignition apparatus. (335.) At high temperatures, it is acted upon by the alkaline hydrates, and by almost all metals, especially tin and lead. I had a platinum crucible perforated, by fusing in it some flint glass, which consists mainly of lead, silicic acid, and potash.

1593. The equivalent of platinum is 99.

#### *Of the Compounds of Platinum with Oxygen.*

1594. Platinum forms a protoxide, consisting of one atom of metal and one atom of oxygen, which may be obtained from the chloride, by the addition of potash. It forms also a bioxide, containing two atoms of oxygen to one of metal, as the name implies. The protoxide acts as an oxybase only; the bioxide, both as an oxybase and oxacid. In the last mentioned capacity it enters into combination with ammonia, in the compound called fulminating platinum, and which we may with propriety call platinate of ammonia, or ammonium. Dr. Thomson alleges the existence of some other oxides of platinum.

#### *Of the Compounds of Platinum with the Halogen Class.*

1595. *Of Chloroplatinic Acid.*—The platinum, in the solution of aqua regia above described, being in the state of a bichloride and acting as an acid agreeably to my fundamental definition, (631,) is capable of combining with other chlorides acting as chlorobases. With either the chloride of potassium, or the chloride of ammonium, (sal ammoniac, 1109,) it forms compounds which are but very sparingly soluble in water. Hence the precipitate resulting from the addition of the last mentioned chlorobase, and the employment of the chloride (or chlorobase) of potassium, in the process recommended by Berzelius. (1589.) But since the bichloride of platinum acts as an acid, it is proper to designate it as a chloroplatinic acid. In this I am supported by the authority of Dr. Thomson. It follows that the precipitates obtained as above described, are severally chloroplatinates of ammonium, and potassium.

1596. The superior solubility of the chloroplatinate of sodium, enables us to distinguish solutions in which this metal exists as the radical, from those in which potassium performs the same part; as with the latter only is orange-coloured precipitate obtained, on adding chloroplatinic acid.

1597. *Of Chloroplatinous Acid.*—This name is given to the protochloride of platinum, as it is, according to Berzelius, capable of combining with the same chlorobases as chloroplatinic acid. Chloroplatinous acid is obtained by exposing the bichloride (chloroplatinic acid) to heat. It is alleged to have a grayish colour, and to be insoluble in water. Its compounds with chlorobases must consistently be called chloroplatinites.

*Experimental Illustrations.*

198. Platinum exhibited in the state of native grains, in the malleable state. Precipitated from its solution chloride of ammonium, and chloride of tin. A precipitate produced in salts of potash by chloride of platinum, distinguishes them from salts of soda. Combustion of platinum with tin-foil.

*of the Nomenclature of Compounds formed with Halogen Bodies, called Double Salts by Berzelius.*

199. In order to present an intelligible view of the discordant names of salts above described, I will here subjoin a table of the names of some compounds formed with chlorine by platina, of which mention has been made (1596.)

*of the various Names given to the Double Chlorides, such as those described in the case of Platina.*

*Names according to the old Theory of the Muriates.*

1,	}	Muriate of	}	Platinum.
oniacal, or Ammonia,				

*Names according to Brande.*

o bichloride of	-	-	-	-	}	Potassium.
						Sodium.
						Ammonium.

*Berzelian Names.*

ure platinico,	-	-	-	-	}	Ammonique.
						Sodique.
						Ammonique.

*as according to Thomson adopted by me, before I was aware of their adoption by this distinguished Author.*

oplatinate of	-	-	-	-	}	Potassium.
						Sodium.
						Ammonium.

*Compounds formed with the Protochloride, by Berzelius designated as follows:*

ure platinoso,	-	-	-	-	}	Potassique.
						Sodique.
						Ammonique.

*as in this Compendium designated by me,—*

oplatinite of	-	-	-	-	}	Potassium.
						Sodium.
						Ammonium.

1600. In order to have the nomenclature of the analogous compounds, in which other chlorobases or chloracids are introduced, it is only requisite to change the corresponding epithet in the formula.

1601. By changing the syllables indicating the halogen ingredient, the nomenclatures of any of the double salts formed by any of the halogen bodies, may be seen, agreeably to the language of Brande, of Berzelius, or of Thomson and myself.

*Of Bromides, Iodides, and Cyanides.*

1602. Bromine forms with platinum a compound analogous in composition to the bichloride of that metal, and which, from its chemical properties, is entitled to the appellation of *bromoplatinic acid*.

1603. Iodine and fluorine both form compounds with platinum. The fluoride of platinum acts as an acid; the properties of the iodide in this respect are unknown.

1604. Cyanogen forms two compounds with platinum. The percyanide combines with cyanobases as an acid, and of course may be designated as *cyanoplatinic acid*.

*Of the Compounds of Platinum with Sulphur.*

1605. Platinum combines with sulphur in two proportions. Both sulphides combine as sulphobases with sulphacids, but the persulphide unites as a sulphacid with sulphobases of the alkalis and metals.

*Of the Power of Platinum, and other Metals in a divided or spongy form, to induce Chemical Reaction.*

1606. In the spongy form in which platinum remains after the chlorine and ammonia of the chloroplatinate are expelled, it has the wonderful power of causing the inflammation of a mixture of hydrogen and oxygen gas. I have ascertained that this power is acquired by asbestos, porcelain earth, and charcoal, merely by soaking them in a solution of platinum, in aqua regia, and subsequent desiccation and ignition. Thenard states, that platinum filings, platinum leaf, or an association of fine platinum wires, exercise, in a greater or less degree, the same power as platinum sponge.

1607. The pulverulent mass, obtained by precipitating platinum by zinc, becomes incandescent in the vapour of alcohol. As the best means of obtaining platinum is that state of minute division in which it is most efficacious in producing this result, Liebig recommends that the chloride should be dissolved in a lixivium of caustic potash with heat; and that while the resulting liquid is still hot, alcohol should be added in small quantities, stirring the mixture until an effervescence arises from the extrication of carbonic acid. This, however, becomes so active as to render a very capacious vessel necessary for the process. The platinum precipitates in the form of a black powder, which is to be separated from the liquid, and washed successively with alcohol, with a solution of potash, with chlorohydric acid, and four or five times with water. When dried, the powder resembles lampblack, and soils the fingers. Nevertheless, it consists only of platinum in a state of minute division, since it may be heated to a cherry-red in the air or in oxygen, without losing weight or undergoing any change in its properties. These are, however, destroyed by incandescence, which restores its metallic appearance. Under the burnisher, it becomes slightly of a metallic gray. In aqua regia, it dissolves without leaving any residue.

1608. Its properties are as follows: like charcoal, it condenses the gases in its pores, with a development of heat; and if, after being deprived of air and moisture by exposure to a vacuum over sulphuric acid, the atmosphere be rapidly admitted, it becomes red-hot. It causes the combustion of hydrogen or alcoholic vapour, when in contact with them with access of air, and becomes incandescent on falling on a surface wet with alcohol. If moistened with alcohol, it converts it, at the expense of the oxygen of the air, into acetic acid and acetic ether. Platinum, however prepared, gradually loses the property of causing a union between oxygen and hydrogen; but this property disappears much more rapidly when exposed to the action of the air, than when protected from its influence. Spongy platinum, moreover, remains effective longer than platinum under any other state; unless that in which it is procured by precipitation by zinc be an exception. Platinum leaf, which in the air is rendered powerless in a few minutes, when in the form of a scroll and included in a close vessel, remains effective for twenty-four hours. The power of producing a union between hydrogen and oxygen, may be restored by immersion in an acid, or by incandescence.



1609. Strips of sheet platinum, after being well cleansed by exposure as the electrodes of a Voltaic series; or by exposure, with certain precautions to acids, were found by Faraday to cause the union of the elements of water.

1610. Platinum is not the only substance which possesses the property of producing the combination of oxygen and hydrogen. Gold, precipitated from its solution by means of zinc and subsequently heated to redness, if assisted by a temperature of  $122^{\circ}$ , causes the union of hydrogen and oxygen. Osmium slowly produces the same effect, at a heat a little below that which is necessary in the case of gold. Spongy nickel acts slowly at the ordinary temperature of the atmosphere. Palladium, rhodium, and iridium produce the same effect on a mixture of hydrogen and oxygen as platinum, though with less intensity. Charcoal, porcelain, glass, and rock crystal produce a union between hydrogen and oxygen, at temperatures lower than that at which it would otherwise take place.

### *Experimental Illustrations.*

1611. A mixture of hydrogen and oxygen inflamed by platinum sponge, or platinated asbestos. Incandescence of platinum powder produced by moistening it with alcohol.



## SECTION III.

### OF SILVER.

1612. Silver exists in nature nearly pure, but usually containing a minute quantity of gold, copper, arsenic, or iron. It also exists in alloys, containing various equivalent proportions of arsenic, antimony, tellurium, or gold. It is found, likewise, in the state of chloride, iodide, sulphide,\* and carbonate, and in a variety of galena, the native sulphide of lead, called, in consequence, *argentiferous* galena. In consequence of its fusibility and insusceptibility of oxidizement,—when any metallic alloy, containing it, is exposed to intense ignition with access of air, the silver is separated from any metal which, when thus exposed, is liable to be converted into an oxide. In the small way, this object is effected upon the *cupel*, in the operation called cupellation. A cupel is a small flat cylinder, made of bone earth obtained by calcination, in the upper surface of which there is a hemispherical cavity. In this cavity any gold or silver to be refined is placed with a portion of lead. The cupel is then placed in a small earthenware oven, called a muffle, and exposed to a heat sufficient to render and keep the metals fluid. Under these circumstances, the lead is oxidized and vitrified, and promotes a similar change in any other metals present, which are susceptible of oxidizement under the circumstances in question. The vitreous matter, thus produced, is absorbed by the bone earth. After the process has endured sufficiently, only the gold and silver, or other noble metals, should any be present, can remain upon the cupel. This stage of the process is indicated by the metallic surface being no longer obscured by any film of oxidized matter. As in the cases in which this process is employed, no other noble metals are liable to be present besides gold and silver, I shall treat of it only in reference to them.

\* The student is requested to recollect that sulphide and sulphuret are synonymous. (686).

1613. From the alloy purified upon the cupel, the silver may be removed by nitric acid, when the gold does not exceed a fourth of the whole. In order, therefore, to enable the nitric acid to dissolve the silver, the mass is fused with the addition of as much of this metal, as will establish the requisite ratio between it and the gold. This is called *quartation*. The process of separating the metals afterwards by nitric acid, is called *parting*.

1614. If the alloy be subjected to aqua regia, the gold only will be taken up. The silver will precipitate as a chloride, and the parting will be effected the easier, in proportion as the quantity present of the last mentioned metal is less.

1615. Silver, contained in argentiferous copper, is extracted by means of lead, in the process called *liqutation*. The alloy is fused with two and a half parts of the metal last mentioned, and cast into thick round cakes. These are subsequently exposed in a reverberating furnace, to a heat sufficient to melt the silver and lead, leaving the copper, which has scarcely any affinity for lead. The silver is afterwards separated from the lead by cupellation.

1616. Pure silver may be obtained from silver coin by various means. The white crystals spontaneously afforded by a solution of the coin in nitric acid, cautiously drained, and washed with a portion of water barely sufficient to remove every vestige of green, yield a solution of pure silver. The residual liquid may be decomposed by copper, and the precipitate redissolved, and crystallized by evaporation; and thus a fresh crop of white crystals may be procured. The whiteness of the crystals may be deemed the criterion of their purity. Silver precipitated by mercury, as in the case of the arbor Dianæ, only requires ignition to render it pure.

1617. *Properties.*—Excepting steel, silver is susceptible of the highest degree of metallic brilliancy; and next to gold, it is the most malleable and ductile metal. In metallic whiteness, it is pre-eminently beautiful, and in tenacity inferior only to iron, copper, and platinum. Its specific gravity is 10.5, and equivalent 108. It is the best conductor of caloric, fuses at a low white heat, is as difficult to oxidize in the fire as gold, but is more liable to tarnish when exposed to the atmosphere, from its susceptibility to the action of sulphur and chlorine. Hence it is blackened by eggs and by salt water.

1618. By the compound blowpipe, electricity, or galvanism, silver is fused, oxidized and dissipated.

1619. Exposed to nitric acid, it is oxidized by one portion, and dissolved by the other. In fact this acid is its proper solvent. The resulting nitrate, when fused and cast into sticks, forms the lunar caustic of the shops. It consists of one atom of acid 54, and one of oxide 116, = 170.

1620. Sulphuric acid, when cold, has no reaction with silver. At a boiling heat, the metal is oxidized at the expense of one portion of the acid; and the oxide, thus formed, is dissolved by another portion, as in the case of nitric acid.

1621. Silver combines with phosphorus, and in minute proportion with carbon and silicon.

#### *Of the Compounds of Silver with Oxygen.*

1622. Silver forms two oxides. The protoxide is obtained by decomposing the nitrate by potash or soda. It is of a deep olive colour, slightly soluble in water, and, according to Thenard, sufficiently alkaline to render syrup of violets green. It **revives simply by the influence of heat, and of course is reducible when heated with those radicals, which, under the same circumstances, combine, per se, with oxygen.**

When thus reduced, it must of course produce the vivid ignition which is consequent to the presence of pure oxygen.

1623. This oxide, by uniting with ammonia, produces a fulminating compound, so dangerous that few persons have been willing to encounter the risk of making it. This should not be confounded with the fulminate of silver, consisting of the same metal and fulminic acid. (1312, &c.)

1624. The peroxide of silver is formed around the wire, proceeding from the positive pole of the Voltaic series, when a weak solution of nitrate of silver is placed in the circuit. It crystallizes in long needles, endowed with a metallic brilliancy. It does not combine with acids, but when presented to them, by a partial relinquishment of oxygen, passes to the state of protoxide. This oxide does not act either as a base or an acid. It detonates with phosphorus, if struck with a hammer while in contact with that substance; and when subjected to ammonia, disengages nitrogen from it by oxidizing the hydrogen.

1625. The protoxide of silver consists of one atom of silver, equivalent 108, and one of oxygen, equivalent 8 = 116.

1626. Some chemists suppose the existence of a suboxide of silver.

#### *Of the Compounds of Silver with the Halogen Class.*

1627. Silver unites with chlorine when heated in it, or presented to it in solution. The resulting chloride is one of the most insoluble combinations. Hence, silver is not soluble in aqua regia, or any other liquid containing chlorine; and on this account, soluble chlorides yield a precipitate, when solutions of silver are added to them.

1628. The chloride of silver is white and tasteless, and, according to Thenard, when exposed to light, is decomposed, forming a subchloride. It combines as a base with the electro-negative, and as an acid with the electro-positive chlorides.

1629. It is susceptible of fusion without decomposition, forming what was called by the old chemists, luna cornea, or horn silver.

1630. Chloride of silver is soluble in liquid ammonia, forming chloroargentate of ammonium. It may be decomposed by hydrogen, if brought into contact with this gas in its nascent state, as when evolved from zinc or iron by a diluted acid. It is easily decomposed by the compound blowpipe, supplied with hydrogen and atmospheric air; also by fusion with the fixed alkalies, or when boiled in water with shreds of iron. The formation and subsequent decomposition of the chloride, is one of the modes of obtaining pure silver.

1631. The chloride of silver is composed of one atom of silver, and one atom of chlorine.

1632. Bromine and iodine form, with silver, compounds analogous in composition to the chloride. The bromide and iodide, acting as acids, combine with the bromides and iodides of the alkalis and metals, acting as bases. A native iodide of silver has been found in Mexico.

1633. Fluorine and cyanogen both combine with silver; the fluoride acts as a base, the cyanide as an acid.

#### *Of the Compound of Silver with Sulphur.*

1634. The sulphide of silver is solid, ductile, easy to cut, of a lead-gray colour, with a metallic brilliancy, more fusible than silver, crystallizable in cubes or octahedra, and indecomposable by fire. It acts as a powerful sulphobase.

1635. This sulphide is produced whenever silver is exposed to sulphur, or sulphydric acid. The blackening of silver spoons by eggs, is ascribed to the existence of a minute portion of sulphur in the albumen. The impression has been entertained that persons, who use the water of the white sulphur springs freely, find silver coin, carried about them, blackened by the sulphur introduced into the blood. This, however, may arise from their frequenting the spring, and thus exposing the silver about their persons to the action of the sulphydric acid gas which is continually evolved from the water. I am, however, far from deeming the fact improbable. It would, a priori, be no more surprising that the animal frame should be imbued with sulphur than with mercury.

#### *Experimental Illustrations.*

1636. Exhibition of an assay furnace and muffle; also of a cupel. Oxidizement and solution of silver in nitric

acid exemplified; also its precipitation by chlorides, phosphates, arsenites, arseniates, copper, and mercury. Fused subnitrate of silver, or lunar caustic, exhibited. (1619.)

## SECTION IV.

### OF MERCURY.

1637. This well known metal is found in nature in the metallic state, pure, and in union with silver; also in the states of sulphide and of chloride. It is obtained principally from the native sulphide, cinnabar, the most abundant and prolific of its ores, by distillation with the hydrate of lime. In this country it may always be procured nearly pure, in the iron bottles in which it is imported. It is alleged that mercury may be purified by distillations from iron filings. I once distilled several hundred pounds in this way for my mercurial reservoir, but did not find it to be quite pure afterwards. A better mode is to digest it at a heat below the boiling point, with dilute sulphuric acid in a glass, porcelain, or stoneware vessel. Under these circumstances, any metal having a greater affinity for oxygen than mercury, will be taken up by the acid.

1638. If on being agitated in a cup of white porcelain mercury does not soil the surface, it may be considered as pure.

1639. When triturated or violently shaken with other matter, so that this may be sufficiently interposed between its particles to prevent them from touching, it is liable to be comminuted into a black or deep blue powder. According to Berzelius, it is in this form that mercury exists in blue ointment. It follows that the method which has been recommended for the purification of this metal by agitating it so as to cause the oxidizement of the more electro-positive metal which it may contain, is pregnant with the evil that a portion of the metal separates with the resulting oxides. There is a large proportion of mercury separates with the lime, during the oxidizement of the radical of this earth in the amalgam of calcium.

1640. *Properties.*—Mercury is the only metal which is liquid at the ordinary temperature of the atmosphere. In

and brilliancy it resembles and rivals silver. It is malleable at  $-39^{\circ}$ , and boils at  $665^{\circ}$ . In some experiments by Faraday, it would appear that mercury vaporizes to a minute extent, whenever the temperature of the air is above  $70^{\circ}$ . At the temperature of fusion its specific gravity is 13.6; but in freezing, it is increased to 14.4.

1. Mercurial compounds are all volatilizable by heat; mercurial salts, when moistened and rubbed upon copper, cover it with a film of mercury.

2. It is alleged that if a drop of any liquid containing mercury be placed upon gold, and touched with the edge of a knife, or a piece of iron wire, the mercury will be precipitated upon the gold.

*Of the Alloys of Mercury with other Metals, called Amalgams.*

3. All metals combine with mercury, directly or indirectly. Its compounds have the generic name of amalgams.

In the case of gold, silver, zinc, lead, tin, and bismuth, the amalgamation is rapidly effected. It is less so when produced with copper, unless when this metal separates from the acids. It is difficult to unite mercury with platinum, and still more so with iron, owing, chiefly, to the great difference in fusibility.

4. Mercury unites energetically with the metals of the alkali series. In the case of sodium, a species of combustion takes place, so that the mass becomes red-hot; and when it is thrown upon mercury, it is repelled with violence and with a disengagement of light.

5. The amalgam of potassium is an efficient instrument in the evolution of the amalgam of ammonium.

6. The equivalents of mercury, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Mercury,	-	-	-	equivalent	202
Oxide,	1 atom mercury with	1 atom oxygen			210
Chloride,	1	"	" 2 atoms	"	218
Sulphide,	1	"	" 1 atom chlorine		238
Hydride,	1	"	" 2 atoms	"	274
Sulphide,	1	"	" 1 atom sulphur,		218
Hydride,	1	"	" 2 atoms	"	234

*Of the Compounds of Mercury with Oxygen.*

1647. There is still some discordancy in the opinions and language of chemists respecting the oxides of mercury. It has been generally held that there are two oxides of this metal; one black, the other red. According to the table of equivalents in the Appendix, the atom of mercury = 202, with one atom of oxygen, forms the black oxide or protoxide, = 210, and with two atoms of oxygen forms the red oxide, peroxide, deutoxide, or bioxide, = 218. Dr. Thomson, conceiving the atom of mercury to have only half the weight here assigned to it, considers the black oxide as consisting of two atoms of metal, and one of oxygen, and consequently designates it as a suboxide. The difference in this case, therefore, is only hypothetical. But Guibourt has advanced that there is only one oxide of mercury, the black oxide being composed, according to him, of the red oxide and metallic mercury. Donovan, on the other hand, has shown that, when a small quantity of calomel is added to a comparatively large quantity of potash, a pure protoxide or suboxide is obtained.

1648. The *protoxide of mercury* may be obtained by digesting the protochloride with an excess of potash. The oxygen and chlorine exchange places, and the chloride of potassium, and protoxide of mercury are formed. This oxide may be precipitated from a solution of the nitrate of the protoxide, by the addition of an alkaline solution. It has likewise been supposed to be produced when mercury is subjected to long continued agitation, in contact with air. It is, however, alleged by Berzelius, that the black powder, thus obtained, is metallic mercury in a state of extreme division, to which it could not be reduced without the interposition of the oxide, resulting from the presence of a more oxidizable metal; that, when the metal is quite pure, and free from the interposition of heterogeneous particles, it undergoes no change by agitation; but that if, under the same circumstances, it be triturated with grease, gum, powdered glass, or sand, it may be reduced to a black metallic powder. He conceives that all the preparations made by triturating mercury with grease, gum, or other viscid substances, contain the metal in a divided state, but not oxidized.

1649. The protoxide of mercury is a black powder, which,

y exposure to light, or to the heat of boiling water, is converted into metallic mercury and bioxide.

1650. The *bioxide* may be procured by long exposure of mercury to a heat sufficient to cause a gentle ebullition, the air having free access. It may likewise be obtained by expelling the acid from the nitrate by heat. Berzelius informs us, that, agreeably to the opinion of some respectable physicians, it is only when procured by the former method that it is fit to be used internally. He attributes his difference to the fact of its sometimes retaining, when obtained from the nitrate, a small portion of nitric acid. This oxide, when in mass, is of a beautiful red colour, but, when powdered, assumes a yellowish appearance. It is decomposed into metallic mercury and oxygen at a heat little below redness. In water it is slightly soluble, and its solution has the property of rendering syrup of violets green.

1651. Both the oxides of mercury act as bases. The bioxide forms with ammonia a fulminating compound.

*Of the Reaction of Acids with Mercury and its Oxides.*

1652. When nitric acid, whether cold or hot, concentrated or dilute, is brought into contact with mercury, one portion of the acid is decomposed, imparting oxygen to the metal; the oxide thus formed being dissolved by the remainder of the acid. When the metal is in excess, the protoxide is principally formed. When the acid is in excess, the bioxide predominates. Usually, more or less of each oxide is formed.

1653. Whether concentrated or dilute, cold sulphuric acid does not react with mercury; but when the concentrated acid is boiled on the metal, the phenomena are analogous to those which ensue in the case of nitric acid. One portion of the acid yields oxygen to the metal; another combines with the oxide thus created.

1654. As in the case of nitric acid, we may have the oxybase of mercury in the state of bioxide, or of protoxide, accordingly as the acid or the metal is in excess, or as the time allowed for oxidizement is greater or less.

1655. Each oxide of mercury forms three salts with nitric acid. When washed with hot water, the bisulphate of the bioxide yields a yellow compound known under the name of *turpeth mineral*, which, according to a recent ana-

lysis by Kane, is a subsulphate, consisting of one atom of neutral sulphate, and two atoms of protoxide, the formula being  $\text{HGO SO}^3 + \text{HGO}$ .

1656. Although in the metallic state, mercury has generally no reaction with acids; yet in the state of an oxide, it is no doubt liable to be combined with any of them. About one hundred mercurial salts are mentioned in Thomson's *Inorganic Chemistry*. With these compounds, without a special motive, it would be worse than useless for a medical student to burthen his memory. But it is fortunate that, in this branch of our knowledge, we are aided by analogy, and that we are enabled, when we hear of an oxacid, to infer that the formation of a corresponding salt with each oxide of mercury is possible. Moreover, agreeably to the received principles of chemical nomenclature, we are enabled to assign to the compound thus imagined, a name which would be recognised by another chemist.

1657. In the metallic state, mercury has no reaction with acids, having hydrogen for their radical, called hydracids, by some chemists; but which are, in this book, designated as halohydric, or amphydric acids. (660.) Yet, excepting in the case of the earths proper, it may be assumed that, when any metallic oxide is presented to any of the hydracids, water will be formed by the oxygen of the one, and the hydrogen of the other; while the metal and basacigen body will unite, and, in a majority of instances, the metal will acquire the same number of atoms of the basacigen body, as it relinquishes of oxygen. It follows, of course, that on subjecting a mercurial oxide to chlorohydric, bromohydric, iodohydric, fluohydric, cyanhydric, sulphydric, selenhydric, or telluhydric acid, a chloride, bromide, iodide, fluoride, cyanide, sulphide, selenide, or telluride, will generally, if not universally, result.

#### *Of the Chlorides of Mercury.*

1658. When a solution of chloride of sodium and of nitrate of the protoxide of mercury are mingled, the oxygen of the oxide, and chlorine of the chloride exchange places; so that protochloride of mercury (calomel) precipitates, while the oxygen and sodium uniting, remain in solution, and in union with the nitric acid.

1659. If the solution of chloride of sodium be added to



on of the nitrate of the bioxide, the two atoms of in this oxide will exchange places with the chlorine two atoms of the chloride; so that the mercury will, atoms of oxygen, acquire a like number of atoms fine, and be thus converted into one atom of bioxide, or corrosive sublimate, which will remain in solution there be enough water present. Thus the quantity fine transferred is regulated by the quantity of oxygen the oxide employed; the protoxide producing the chloride, the bioxide the bichloride. (1657.)

1. The complex affinity which causes these changes, is either in the wet or dry way; that is, whether substances be mixed in solution, or sublimed together. sulphate of the bioxide of mercury produces these when sublimed with certain compounds of chlorine chloride of sodium for instance. Corrosive sublimate thus procured; and, by trituration with mercury, and sublimation, and washing in boiling water, may be converted into calomel; or the bisulphate, by trituration with a further portion of the metal, being converted into monosulphate, forms calomel directly by sublimation with an alkali salt.

2. The process for the manufacture of the protoxide, has been improved by causing its nascent vapour to be mingled with steam, which, interposing between the particles, prevents them from adhering as they condense. They are thus obtained in a state of more minute division, and can be effected by trituration, and the aqueous solution, in condensing, combine with and remove any excess of corrosive sublimate which may be generated simultaneously with those of the calomel. Calomel thus prepared, has been distinguished as Howard's hydrosulphate.

3. Chlorine does not combine with mercury in the mode above mentioned only. A jet of chlorine burns vigorously in mercurial vapour, forming a bichloride.

4. The chlorides of mercury may likewise be obtained by subjecting the oxides to chlorohydric acid; in which case the hydrogen of the acid, and oxygen of the oxide form water, while the mercury and chlorine unite; the oxide giving rise to the protochloride, the bioxide to the bichloride, as already explained. (1657.)

5. The processes for manufacturing these important

compounds of mercury, are very numerous. They have, however, but one object—that of presenting chlorine and mercury to each other in due quantities, and intimately mingled. When the chlorine is in excess, corrosive sublimate is formed; when the metal predominates, calomel.

1665. The *protochloride* is white and crystalline, but usually more compact than corrosive sublimate. It is tasteless, inodorous, and unalterable by exposure to the atmosphere if protected from light; but by this it is blackened, and partially reduced to the metallic state. It is blackened by alkaline solutions, by the generation of protoxide; and when the surface is removed, it appears yellow, so that a scratch made with the nail, is productive of a yellow streak. It is less volatile than the bichloride. This chloride acts as a base.

1666. The *bichloride* or corrosive sublimate is white, more or less crystalline, and transparent. It is soluble in about twenty parts of cold water, but more so in hot water, whence crystals are obtained by refrigeration. It dissolves in two parts of alcohol, and in three parts of ether, by weight. It is not soluble either in sulphuric or nitric acid. On the application of heat, it sublimes unchanged. When added to an alkaline solution in excess, a yellow hydrated bioxide of mercury precipitates. The proportions being reversed, as when an alkaline solution is dropped into the solution of this chloride, a compound of the bioxide and bichloride is precipitated, which is of a brick-red colour. Berzelius designates this compound as the *chlorure mercurique basique*, while Thenard gives it the name of *bioxido-chlorure*. The latter appellation, changed to *oxychloride*,\* in order to render it consistent with the nomenclature adopted in this work, and more easy to pronounce, I shall employ for this, and for analogous compounds formed with other metals.†

1667. Ammonia throws down from a solution of the bichloride, a compound called ammoniated mercury in the

\* I believe this name is now generally preferred.

† This compound probably furnishes one among many other instances, in which an electro-positive compound of one basigen body, unites with an electro-negative compound of another.

It might indeed be alleged, that in this case the metal acts the part of a basigen body, agreeably to my definition, (623,) as it enters into two compounds, one electro-negative, the other electro-positive, which form a tertium quid. This view of the subject corroborates the remark, which I have elsewhere made, that nature has not fitted her bodies for distinct classification; and that consequently there will be cases, in which some of the bodies associated in one class, will appear to belong to another.

ted States' Pharmacopœia, but more generally known hydrargyrum precipitatum album, or white precipitate. The new, derived from organic chemistry, has lately led to a new view of this preparation, which it will be more convenient to present, in treating of that branch of the science.

668. The bichloride of mercury has a most nauseous allic taste, and is a virulent poison. The best antidote is albumen, which may be given in the form of the white of eggs, diluted with water. This chloride, acting as an acid, combines with the chlorides of ammonium, potassium, sodium, barium, and magnesium. As a base it combines with chlorohydric acid, forming a crystalline compound, which effloresces and is decomposed when exposed to the air.

669. The salt, long known under the antiquated appellation of *sal alembroth*, and formed by mixing solutions of ammoniac and corrosive sublimate, is now by Berzelius considered as a double salt, and by Bonsdorf, a chlorohydrate. This last mentioned name accords with the notion of acidity and basicity which I have proposed.

#### *Of the Bromides, Iodides, Fluorides, and Cyanides of Mercury.*

370. As respects the means of their production, the ratio of their constituent atoms, and their qualities in general, there is the greatest analogy between the compounds formed by mercury with the halogen class. Hence, being treated particularly of the chlorides, I shall treat with the utmost brevity of the compounds named at the head of this article.

371. Bromine forms two compounds with mercury. The *protobromide* is white, pulverulent, and insoluble. It is obtained by the reaction of the iodide of potassium with the nitrate of the protoxide of mercury.

372. The *bibromide* is formed by subjecting mercury to the action of bromine and water. It is soluble, crystallizable, fusible, capable of volatilization, and colourless. With the alkaline bromides it acts as an acid.

373. The *protiodide of mercury* is obtained by the reaction of the iodide of potassium with the nitrate of the protoxide of mercury. It is olive green, insoluble in water, and corresponds in composition with the protochloride.

374. The *biiodide* may be procured by adding the iodide of potassium to a solution of the bichloride of mercury. A reciprocal decomposition takes place, and the biiodide of mercury and the chloride of potassium are formed. The biiodide is fusible, volatile, and of a transcendently beautiful violet colour. As an acid it combines with the iodides of many of the metals and alkalies, and with the iodides of zinc and iron. As a base it combines with iohydric acid. It consists of one atom of mercury, combined with two atoms of iodine.

1675. Another iodide exists, containing less iodine than the biiodide, but more than the protiodide.

1676. Although cyanogen does not combine with mercury directly, a *bicyanide* is obtained when the bioxide of this metal is digested in water with Prussian blue. I shall more fully explain this process when treating of iron.

1677. The employment of the bicyanide in the evolution of cyanogen and cyanhydric acid, has already been mentioned. (1296). The bicyanide of mercury forms combinations with the alkaline cyanides, in which it plays the part of an acid.

1678. The *fluoride of mercury* is obtained by the action of fluohydric acid on the bioxide. It acts both as an acid and base. It is yellow, volatile, and when volatilized in platinum or glass vessels, corrodes them. If subjected to water, it is resolved into a soluble and an insoluble compound.

### *Of the Compounds of Mercury with Sulphur.*

1679. Agreeably to the list of equivalents near the beginning of this section, mercury forms with sulphur, a protosulphide and a bisulphide. When a weak solution of the nitrate of the protoxide of mercury is impregnated with sulphydric acid, the *protosulphide* is produced in the form of a black precipitate. It appears to be an unimportant compound. The protosulphide acts as a sulphobase.\*

1680. The *bisulphide* may be generated by impregnating with the same gas a solution of the bichloride. Thus obtained, it resembles the protosulphide in assuming a black colour, which, however, may be changed to red by sublimation.

1681. The bisulphide (artificial cinnabar) is procured in the large way, by fusing one part of sulphur, stirring in gradually six or seven of mercury, and subjecting the resulting black mass to the process of sublimation in close vessels.

1682. Kirchoff procured cinnabar by a long continued trituration of mercury and sulphur with a solution of caustic potash, aided by a gentle heat.

1683. Bisulphide of mercury is attacked neither by sulphuric, nitric nor chlorohydric acid, nor by caustic alkaline solutions; but when subjected to chlorine, either in aqueous solution as in aqua regia, or in the gaseous form, it is converted into bichloride of mercury, and bichloride of sulphur.

1684. Berzelius alleges that this bisulphide performs the part of a base in combining with the æriform sulphacids. It also forms compounds with the bichloride, bibromide, biiodide, and bifluoride of mercury.

1685. Equal parts by weight of mercury and sulphur, triturated together, form a black mass, called, from its colour, *Ethiops mineral*, which is now considered as a mixture of bisulphide of mercury and sulphur.

\* Guibourt, who has been mentioned as questioning the existence of more than one oxide of mercury, has alleged his disbelief in the existence of more than one mercurial sulphide; the black sulphide being, in his opinion, a mixture of the red with the metal. Sefstrom controverts this allegation, and Thenard, citing his opinions and that of Guibourt, inclines in favour of those of Sefstrom. Thenard alleges that at least the protosulphide exists as a base, in combination with sulphides, acting of course as sulphacids agreeably to my definition. (631)

*Of the Phosphurets of Mercury.*

1686. In its *habitudes* with mercury, phosphorus displays that analogy with sulphur which is in general so remarkable. It forms, according to Berzelius, a red and a black phosphuret. The latter results from the digestion of bioxide of mercury with phosphorus and water; the former, from exposing phosphorus to the vapours of the bichloride of mercury.

*Experimental Illustrations.*

1687. Ebullition and distillation of mercury. Its compounds with oxygen and sulphur, exhibited. Action of nitric acid and of sulphuric acid on the metal. Resulting salts, subjected to hot water. Black oxide and red oxide, severally dissolved in nitric acid. Chlorohydric acid precipitates calomel from the one, but occasions no precipitate in the other. Fixed alkalies and alkaline earths produce a black precipitate in the nitrate of the black oxide or protoxide, an orange precipitate in the nitrate of the red oxide or bioxide. Similar results obtained by adding them to calomel and corrosive sublimate; the former giving the black, the latter the red oxide. Hydrargyrum precipitatum album, precipitated from solution of bichloride by ammonia. Solutions of the different mercurial oxides precipitated by iodide of potassium. Inflammation of chlorine with mercurial vapour. Explosion of fulminating mercury. Diversity of precipitates produced by adding bichloride to an excess of alkali, or adding the latter to an excess of bichloride. (1666.)

*Combustion of Mercury with Chlorine.*

1688. This experiment may be performed by means of the apparatus represented by the following cut. Let there be a glass globe, furnished with a neck and tubulure, and holding about two gallons of chlorine. Into the neck, let a trumpet-shaped tube, B, reaching to the bottom, be fastened air-tight by means of a cork.

1689. Let another tube, about fifteen inches in length, and tapering towards one end, so as to form a capillary orifice, be fastened, at the other end, into the lateral tubulure of the globe. Provide a globular receiver, R, with a neck on one side, and a perforation on the other, opposite the neck.

1690. Let the lower part of this vessel be occupied by about a gill of mercury, and exposed to a chauffer of coals, so as to fill the whole cavity of the vessel with the vaporized metal. Under these circumstances, introduce the pipe, D, proceeding from the lateral tubulure, into the neck of the receiver, so that the capillary orifice may be near the perforation; and immediately afterwards pour chlorohydric acid into the tube, B. This will subject the chlorine to pressure without absorbing it, and consequently cause it to escape in a jet from the capillary orifice in the pipe. Hence, mingling with the vaporized mercury, it will produce a feebly luminous flame.

1691. Instead of using the globe and its appendages, I have, in a majority of instances, employed a tubulated retort, with a long narrow beak, for the production of the jet of chlorine. The retort being sufficiently supplied with manganese, and a



glass funnel with a cock being fastened into the tubulure, as much chlorohydric acid is allowed to enter through the funnel, as will generate a sufficient quantity of chlorine to produce a jet from the capillary orifice, in which the beak of the retort is purposely made to terminate. The beak of the retort being made to occupy the place of the tube, represented in the figure as proceeding from the globe, the experiment is, in other respects, the same as that above described.

1692. Since this engraving was made, for the purpose of supplying chlorine, I have found my self-regulating reservoir of chlorine, to render the performance of this experiment more convenient and less precarious than the apparatus above represented. (788, 975.)

## SECTION V.

### OF COPPER.

1693. Copper is occasionally found in nature in the metallic state; also in those of oxide, carbonate and sulphide. It is obtained principally from the sulphide. The sulphide being acidified and volatilized, and the metal oxidized by torrefaction, the resulting oxide is decomposed by heat and charcoal.

1694. The copper of commerce contains, according to Berzelius, a minute portion of sulphur and carbon. It may be purified by solution in concentrated and boiling chlorohydric acid, and subsequent precipitation by a bright plate of iron.

1695. *Properties.*—The lustre and peculiar colour of this metal are too well known to need description. Ex-

titanium, it is the only red metal. It is very malleable and ductile, and next to iron in tenacity. It fuses at white heat. Alloyed with a small quantity of tin, it forms bronze; with a larger quantity, bell metal. Alloyed with zinc, or subjected to the vapour of this metal, it is converted from calamine when heated with charcoal, it is changed into brass.

6. If a current of ammoniacal gas be passed over copper heated to bright redness in a tube, the gas is decomposed, and the copper becomes brittle, although its weight is but slightly, if at all increased. This change is supposed to be due to a different aggregation of the particles of the copper, induced by the formation and subsequent decomposition of a nitruret of copper.

7. The blade of a knife, or any bright piece of iron, is a test for copper in solution; as a film of this metal will be precipitated upon the iron or steel and communicate to it the appearance of copper. Ammonia, added in excess, produces a blue colour in water containing a very minute quantity of copper, (523, &c.) It has been ascertained that it requires twice as much copper to produce a blue tinge with ammonia, as to produce the cyaniferous acid of the cyanoferrite of potash the appropriate hue of the cyanoferrite of copper, is a peculiar rich reddish-brown. With this test I detected copper in the rain water, proceeding from the gut of a copper roof.

8. Phosphorus combines with copper in various proportions, forming unimportant compounds. When present in small quantity, it has an effect upon this metal similar to which carbon has on iron, rendering the copper tough for cutting instruments. Carbon and silicon combine with copper.

9. The specific gravity of copper is nearly 9.

10. The equivalents of copper, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

oxide,	2 atoms copper with 1 atom oxygen,	-	32
protoxide,	1 atom " 1 atom "	-	72
,	1 atom copper with 2 atoms oxygen,	-	40
le,	2 atoms " 1 atom chlorine,	-	48
oxide,	1 atom " 1 atom "	-	100
le,	2 atoms " 1 atom sulphur,	-	68
sulphide,	1 atom " 1 atom "	-	80
		-	48

*Of the Compounds of Copper with Oxygen.*

1701. There are three oxides of copper, a dioxide, protoxide, and a peroxide.

1702. Every one is familiar with the appearance of the *dioxide*; since it forms the dull red exterior coating of copper, as it comes to us from the manufacturer. When this oxide is subjected to liquid chlorohydric acid, a double decomposition ensues, and water and a dichloride of copper are formed, the latter remaining in solution. Subjected to nitric acid, the dioxide is converted into protoxide by one portion of the acid, and dissolved by the other. By igniting the protoxide with metallic copper, the anhydrous dioxide is produced. On mingling solutions of potash and of the dichloride, an orange-coloured hydrate of the dioxide precipitates. It is difficult to wash and dry this compound without partially converting it into protoxide.

1703. The *protoxide of copper* is of a brownish-black colour. It is formed upon sheet copper, when exposed to a bright red-heat with access of air. To obtain it, however, Thenard recommends that the nitrate or sulphate be intensely ignited in a stoneware retort, by which means the acid is volatilized, and the protoxide remains. This oxide is formed when copper is dissolved in nitric or sulphuric acid, and enters into combination with them, forming a nitrate, or sulphate.

1704. Thenard alleges that it is soluble in ammonia only when combined with water or some acid; and that it is insoluble in the fixed alkalies, whether hydrous or anhydrous.

1705. That the fixed alkalies promote its *oxidization* is evident; since sheet copper, or brass, moistened with alkaline solutions, always becomes green in the air. I think it probable, that carbonic acid co-operates in producing this result.

1706. The *peroxide of copper* is formed by mingling the bioxide (deutoxide) of hydrogen with a weak solution of nitrate of copper, and adding just enough alkali to decompose all the nitrate. These conditions being realized a brownish-yellow gelatinous mass subsides, which, after being washed upon a filter with cold water, and dried in the vacuum of an air pump over sulphuric acid, forms the peroxide. This oxide has no taste or smell.



1707. The dioxide of copper acts feebly as a base, the protoxide energetically, and the peroxide plays the part either of a base nor of an acid.

1708. Nitric acid diluted nearly to the specific gravity of 1.2, protoxidizes and dissolves copper, producing a blue solution, which yields, by evaporation, elegant blue crystals. The ignition which ensues when these crystals are pulverized, moistened, and rolled up in tinfoil, has been adduced as an exemplification of the influence of water in promoting chemical reaction. (829.)

1709. The crystals of nitrate of copper are of a deeper blue than those of the sulphate, and are deliquescent. At moderate temperature, these crystals fuse, and lose a part of their water of crystallization.

1710. Sulphuric acid, boiled on copper, oxidizes and dissolves it without heat, as nitric acid does. The resulting compound forms the blue crystals of the sulphate, called in commerce *blue vitriol* or *blue stone*. (494.)

1711. A compound is obtained by triturating sulphate of copper with carbonate of ammonia, called *cuprum ammoniatum* (ammoniated copper) in the Pharmacopœias.

1712. This contains the ammoniacal sulphate of copper, with some portion of the carbonate undecomposed. It may be a mixture of ammoniacal sulphate, and ammoniacal carbonate of copper. It is designated as ammoniated copper in the United States' Dispensatory; and the authors allege that there is some obscurity as to the mode in which its ingredients are associated. It has been stated above, that the protoxide of copper is not soluble in ammonia, unless when united with water acting as hydric acid, or with some other substance capable of performing the part of an acid. Berzelius mentions that the protoxide of copper may be kept in a bottle containing liquid ammonia, without tinging it blue; but that the introduction of only a few drops of any ammoniacal salt, the carbonate for instance, causes the well known striking blue colour of the cupreous solution, formerly called *aqua saphirina*. He also alleges that *cuprum ammoniatum* contains the ingredients in such proportion, that the alkali saturates twice as much acid as the copper.

*Of the Compounds of the Oxides of Copper with Acetic Acid.*

1713. The oxides of copper form salts with almost every acid, whether mineral or vegetable. Among these, none are better known than its combinations with acetic acid, of which one is designated in commerce as verdigris, the other as crystals of Venus.

1714. *Crude verdigris* is a mixture of neutral acetate and subacetate of copper, with some impurities.

1715. *The neutral acetate* crystallizes readily, and in the crystalline form has received the name of crystals of Venus; Venus having been one of the names given to copper by the old chemists.

1716. *The subacetate* consists of one atom of acid with two of protoxide, while the neutral acetate consists of one atom of each constituent.

1717. *The salts of the protoxide of copper* are all of an intensely blue or green colour. This does not appear to be true in the case of the dioxide; since, according to Berzelius, when verdigris is subjected to heat, colourless crystals of the acetate of the dioxide sublime, so as nearly to fill the beak of the retort. Thenard alleges that when the hydrated dioxide is subjected to liquid ammonia, a colourless solution of it results.

*Of the Compounds of Copper with the Halogen Class.*

1718. *A chlorohydrate of the dichloride of copper*, acting as a chlorobase, may be prepared by the action of chlorohydric acid on a mixture of the protoxide of copper, and finely divided metallic copper. From this chlorohydrate, the dichloride may be precipitated by water. It is likewise produced by heating the protochloride in glass vessels, by which one-half of the chlorine is expelled. This chloride may also be obtained from the protochloride, by digestion in chlorohydric acid with copper shavings or filings. When thus evolved, it subsides in crystals, which can only be dried in vacuo over sulphuric acid, as in the air they are converted into a compound of the dioxide with the protochloride, forming of course an oxychloride.

1719. *The dichloride* is soluble, crystallizable, and fusible by heat. It consists of two atoms of copper, and one of chlorine.

1720. *The protochloride* may be formed either by the reaction of chlorohydric acid with the protoxide, or by the combustion of copper wire or leaves in chlorine. It is of a bluish-green colour, and an astringent taste. It is crystallizable, fusible, and decomposable by heat. This chloride attracts moisture, and is very soluble in water. Characters written with a solution of it, remain invisible until heated, when they become yellow. It constitutes, of course, a species of sympathetic ink. The protochloride acts as an acid with the chlorides of potassium and ammonium, and with other chlorobases, forming with them chloroplates.

1721. No compound of copper with bromine is mentioned by Berzelius or Thenard. Those formed with iodine appear to be of no importance. With fluorine, copper forms two compounds, a protofluoride, and a perfluoride. The protofluoride acts as a base, the perfluoride both as a base and an acid. Cyanogen enters into combination with copper in two different proportions.

*Of the Compounds of Copper with Sulphur and Selenium.*

*Disulphide of copper* may be produced by the fusion of the metal, or its sulphur. It is found pure in nature, and likewise combined in definite amounts with the sulphides of antimony, arsenic, bismuth, and iron, in which sulphur is usually divided equally between the metals. Berzelius alleges it to be a powerful sulphobase. Yet, in its combination with the sulphide of iron it cannot be supposed to act as a base, as iron is more electro-positive than copper. The affinity between the last mentioned sulphides is so energetic, that the sulphocuprate of iron cannot be decomposed by the united action of carbon and alkali.

*Protosulphide of copper* is formed when this metal is precipitated from its solution by sulphhydric acid.

Copper, by fusion with various sulphides of the alkalifiable metals, is made to combine with several proportions of sulphur, but the resulting compounds are unim-

The union of copper with selenium is productive of heat and light; in which case, as in others, the analogy between selenium and sulphur is sustained. The compound is a diselenide. It is found in nature, but does not appear to possess interesting properties. A protoselenide is formed when copper is precipitated from its solution by selenhydric acid.

*Experimental Illustrations.*

6. Solution of copper in nitric acid, and its precipitation by iron. Effects of ammonia; also of cyanoferrite potassium, on solutions of copper. Crystals of the nitrate, nitrate, acetate, and subacetate, exhibited; also solutions. Exhibition of the protoxide, and of copper superficially dioxidized.



## SECTION VI.

## OF LEAD.

7. Lead is found in nature, in union with sulphur and with oxygen, likewise united, in the state of an oxybase, severally with chromic, stannic, phosphoric, molybdic, carbonic, and arsenic acids.

1. Lead is procured chiefly from the native sulphide, known among chemists and mineralogists under the name of *galena*, which is the most abundant and prolific of its ores. The metal is liberated from galena by exposing it to the flame of a reverberatory furnace, which, oxidizing and expelling the sulphur, liberates the lead, partially in the state of oxide, principally in the metallic state. The protoxide of this metal in a semivitrified state, called *minium*, is largely obtained in the process of cupellation, already described. It is obtained by means of procuring silver from argentiferous galena, or from alloys in which it exists in union with more oxidizable metals. (1612.)

2. From any of its oxides, the metal is easily obtained by heat and reduction.

3. In the small way, a great majority of its combinations will yield a metallic globule, by exposure, on charcoal, to the deoxidizing or carbonizing flame of the blowpipe.

1731. *Properties.*—The colour, lustre, and malleability of lead are well known. It fuses at about 600° F. Its specific gravity is 11.352. In large masses it is pre-eminently ductile, as it may be drawn into pipes of four inches bore; but it is too deficient in tenacity to be drawn into fine wire. It is very useful to chemists, being employed to construct the chambers and vessels used in the manufacture of sulphuric acid, of chlorine, and of the bleaching and disinfecting salts.

*Of the Compounds of Lead with Oxygen.*

1732. The following are the only known compounds of lead with oxygen, with equivalents of the metal, and of those oxides:—

Dioxide, or <i>dross</i> , probably	2 atoms lead,	208	
	1 atom oxygen,	8	
		—	216
Protoxide,	1 atom lead,	104	
	1 atom oxygen,	8	
		—	112
Bioxide,	1 atom lead,	104	
	2 atoms oxygen,	16	
		—	120
Red oxide, or minium,	3 atoms lead,	312	
	4 atoms oxygen,	32	
		—	344

1733. The *protoxide of lead*, as we find it in the shops under the appellation of litharge, is of a yellow colour when in mass, but reddish-yellow when pulverized. In the pulverulent form it is known in commerce by the name of *massicot*. It appears to be soluble in pure water, but is rendered insoluble by the presence of the smallest quantity of chloride of sodium or of any earthy matter. The protoxide of lead acts both as an acid and a base. In the latter capacity, it unites with the more powerful acids; in the former, with the earths and alkalies.

1734. When the protoxide of lead is powdered and heated nearly to redness, and then suffered to cool slowly, it is converted into a substance called *minium* or *red lead*, which is largely consumed as one of the materials of flint glass. Formerly minium was considered as a distinct oxide, and to this view of its composition Berzelius inclines. Thenard alleges, upon the authority of experiments made by Dumas, that it consists of three atoms of lead united to four of oxygen, and infers that it is a compound of one atom of the bioxide, and two of the protoxide.

1735. When minium is exposed to a red heat, it evolves oxygen, and is converted into the protoxide.

1736. *The bioxide of lead* is obtained by the action of nitric acid on minium. If minium be a sesquioxide, one portion of it yields half of an equivalent of oxygen to another portion, and forms a bioxide, while it passes to the state of protoxide, and is taken up by the acid. But if the opinion of Thenard and Damas be correct, it must be inferred that nitric acid dissolves the protoxide, and thus extricates the bioxide previously existing in the mass.

1737. The bioxide is of a flea-colour, and is convertible by heat, first into minium, and then into protoxide. When triturated with sulphur, inflammation ensues. According to Thenard, this oxide never acts as a base, and but seldom as an acid.

1738. Berzelius alleges that the gray pellicle or dross, which forms on the surface of lead when exposed to the air, and which accumulates in greater quantities when the metal is heated, is a dioxide of lead. He also states that this oxide may be obtained by the decomposition of oxalate of lead by heat. Some recent experiments of Mr. Boussingault tend to confirm this opinion.

1739. The habitudes of lead with nitric, sulphuric, and chlorohydric acid, are so analogous to those of mercury with the same acids, that I do not deem it necessary to do more than point out the analogy; at the same time mentioning that, in the case of lead, no compounds are formed by oxacids with any oxide besides the protoxide; and that the resulting compounds have an insolubility more marked and invariable. Of all the important acids, only nitric and acetic acid form soluble compounds with lead. Consequently, as in any mixture, those ingredients which form insoluble combinations, always exercise a superior affinity, it follows that, from its solutions, this metal will be precipitated by any of the important salts, excepting the nitrates or acetates. Thus it will be precipitated by sulphates, phosphates, carbonates, borates, oxalates, chromates, arseniates, arsenites, tartrates, citrates, mallates, meconates, benzoates; also by any of the soluble compounds of the halogen bodies, or any of the amphydric or halohydric acids. (860.)

*Of the Compounds of the Protoxide of Lead with Acetic Acid.*

1740. Lead is oxidized and dissolved by acetic acid and forms the acetate, called in commerce *sugar of lead*. This name was given to the acetate of lead in consequence of its taste, which is sweet and astringent. It is crystallizable, soluble in water, and decomposable by heat.

1741. The acetate of lead, consisting of one atom of oxide, and one atom of acetic acid, by digestion with protoxide, whether in the form of litharge or of massicot, may take either one or two additional atoms of oxide, forming a *diacetate* consisting of two atoms of oxide and one of acid, or a *triacetate*, consisting of three atoms of oxide and one of acid.

1742. By *boiling* a solution of the acetate upon an excess of the protoxide, a *hexacetate* may be obtained, consisting of six atoms of oxide and one of acid. This compound may be produced also, by decomposing the acetate by an excess of ammonia. It forms, when dried, a white powder, slightly soluble in boiling, but insoluble in cold water.

1743. Goulard's extract, of which one "fluidrachm" agreeably to the U. S. Pharmacopœia, is to be added to a pint of distilled water to make *lead-water*, is usually considered as a diacetate, and called the subacetate; but from the formula, it must be evident that it may contain enough of oxide to make it partially, if not wholly, a triacetate.

1744. It appears to me that medical practitioners, not ignorant of the difference which exists in composition between these acetates, are too inattentive to the possible diversity of their effects.

1745. When an acetate, containing more than the proportion of one atom of oxide to one of acid, is brought into contact with carbonic acid gas, a precipitate ensues of carbonate of lead. Hence lead-water may be used as a test for carbonic acid, producing results on breathing it, or upon adding it to a solution of any carbonate, analogous to those produced by lime-water under like circumstances.

*Of Carbonate of Lead.*

1746. When exposed to the fumes of vinegar, which consist of acetic acid and carbonic acid gas, lead is

by the acetic acid, and combines with the carbonic forming ceruse, or the white lead of commerce.

17. According to Thenard, the best process for obtaining the carbonate of lead, is to pass carbonic acid through a solution of the diacetate. Half the lead is precipitated in the state of carbonate, and the remainder remains in solution as an acetate. The solution of acetate is reduced to a diacetate by boiling it with oxide of lead, and subjected to carbonic acid as before. In this way carbonate of lead of the best quality is procured, with comparatively little waste of the acetic acid. Carbonate of lead is found in nature.

*Of the Compounds of Lead with the Halogen Class.*

The analogy between the habitudes of lead and mercury with acids, alluded to, is not greater than that which exists between their habitudes with the halogens. Analogous reciprocal decompositions ensue, whether solutions of the oxysalts of lead or mercury be mingled with solutions of chlorides, bromides, fluorides, or cyanides of the alkalifiable metals.

The chloride of lead is white, crystallizable, soluble in thirty times its weight of water, and has a sweet and astringent taste. When exposed to a red heat it melts, and forms a mass formerly called *plumbum corneum*, from its resemblance to horn. It can be pushed to redness, and the access of air be permitted, the chlorine is volatilized; and the remainder is found to constitute an *oxychloride*. Several oxychlorides exist, containing the oxide of lead, united to the chloride in various proportions. One of these is found native in England.

The bromide, iodide, fluoride, and cyanide of lead, which may, as above mentioned, be generated by means analogous to those by which the chloride is obtained, are of little practical importance to make it expedient to notice them particularly. The fluoride acts as a fluobase, the cyanide as a cyanobase. The former is decomposed by the fluacids of boron and silicon, the latter with cyanoferrous (ferrous) acid. (1299, &c.)

*Of the Compounds of Lead with Sulphur and Selenium.*

Sulphur forms three compounds with lead, a disulphide, a protosulphide, and a selenosulphide. Of these, the only compound which I deem it proper to notice, is the protosulphide, which has already been adverted to as the principal ore of lead, called galena. This sulphide may be formed artificially by heating lead and sulphur together. The protosulphide of lead is tasteless, inodorous, indecomposable by heat, and more fusible than lead. It acts as a sulphobase, and is composed of one atom of lead united to one atom of sulphur.

The selenide of lead may be procured by exposing lead, mingled with selenium, to heat. When thus obtained it is gray, but by friction it becomes polished and like silver. It is found in nature.

*Experimental Illustrations.*

1. Solution of lead in nitric acid. Its solutions are precipitated by sulphates, chlorides, phosphates, and chromates. Also by sulphydric acid. Precipitation of carbonate of lead from the subacetate by the carbonic acid of the blowpipe flame. Galena decomposed by the blowpipe flame.

## SECTION VII.

## OF TIN.

1755. This metal is found in the state of oxide, and in that of sulphide. The sulphide is rare, and contains much copper. The ore of tin, which is the principal source of the metal, is the bioxide which is reduced by heat and charcoal. Tin is sold in commerce under the name of *block tin*, to distinguish it from tinned iron plates, vulgarly called tin.

1756. *Properties.*—The colour and lustre of tin may be seen in utensils newly made of tinned iron. It is very malleable and ductile; tin-foil being only  $\frac{1}{1000}$ th of an inch thick. Tin tarnishes slightly by exposure to the air. It is distinguished by producing a peculiar crackling noise, when its ingots are bent to and fro. It melts at  $442^{\circ}$  F. Its specific gravity is 7.9.

1757. The equivalents of tin, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Tin	-	-	-	-	59
Protoxide	1	atom metal,	1	oxygen,	67
Bioxide	1	"	2	"	75
Protochloride	1	"	1	chlorine,	95
Bichloride	1	"	2	"	131
Protosulphide	1	"	1	sulphur,	75
Bisulphide	1	"	2	"	91

*Of the Compounds of Tin with Oxygen.*

1758. The *protoxide of tin*, may be procured by adding potash to the *protochloride*. A reciprocal decomposition takes place between the oxide of potassium and *protochloride of tin*, which results in the formation of the chloride of potassium, and *protoxide of tin*. The former remains in solution, and the latter precipitates in the state of a white hydrate. From this hydrate the water may be expelled by heat; and a grayish black anhydrous protoxide is thus obtained, which is liable, by contact with an ignited body, to take fire, and consequently to be converted into the bioxide. The hydrate is likewise combustible, though in a less degree.

1759. The hydrated bioxide of tin may be speedily obtained by the reaction of tin-foil or tin powder with concentrated nitric acid, which is decomposed with great violence, bioxidizing the metal without dissolving it. This oxide may be obtained in the same hydrated state, by precipitation from the bichloride by an alkali. The hydrates thus obtained, though in composition the same, are different in properties. Both are soluble in alkalis, but only the latter is soluble in acids. This diversity continues even after they are severally dissolved by alkaline solutions, and subsequently precipitated by acids. These hydrated bioxides of tin are, therefore, conceived to present a case of isomerism. (1153.)

1760. We may convert the bioxide, as obtained by means of nitric acid, into the other modification, by first changing it into a chloride, and then precipitating it by potash. According to Thenard, if the precipitated bioxide be subjected to heat, it becomes insoluble in acids.

1761. An *anhydrous bioxide of tin* may be obtained by subjecting tin to intense heat in contact with air. It is white, infusible, and indecomposable by heat: it reddens moistened litmus paper when placed on it. This oxide is frequently found crystallized in nature. It is employed in the arts for the manufacture of enamel, and, under the name of putty, in grinding glass, and in making a paste for boxes. The bioxide of tin acts both as an oxacid and an oxybase, combining, under favourable circumstances, with either acids or alkalis.

1762. *Concentrated sulphuric acid*, when cold, has no action on tin, but with the assistance of heat dissolves it, disengaging sulphurous acid gas, and forming a sulphate of the protoxide or bioxide.



1763. The reaction above alluded to, between concentrated nitric acid and tin, when the tin is in a state of minute division, is followed by a rise of temperature, a decomposition of the acid, the evolution of nitrogen nearly pure, and the formation of the bioxide of tin. If the nitric acid be diluted so as to have a specific gravity of 1.114, and the temperature be prevented from rising by cold water, or other refrigerating applications, no gas is disengaged; since, water being decomposed simultaneously with a portion of the acid, the nitrogen and hydrogen which are thus liberated, unite to form ammonia. This combines with part of the nitric acid; so that at the close of the operation we obtain nitrate of ammonia, mingled with the nitrate of the protoxide of tin.

#### *Of the Compounds of Tin with the Halogen Class.*

1764. *A crystalline hydrate of the Protochloride of tin*, may be obtained by subjecting the metal, in a divided state, to the action of chlorohydric acid, and then crystallizing the resulting solution by evaporation. The protochloride may be procured in an anhydrous state, either by subjecting this hydrate to a temperature sufficiently high to drive off the water, or by exposing a mixture of the bichloride of mercury and metallic tin to a red-heat. When exposed, either in the solid state or in that of solution, to the action of the air, or of liquids containing oxygen, the protochloride attracts that gas, and is converted into an oxychloride. (1866.) It is probable that in this case a portion of the protochloride is decomposed, the chlorine forming a bichloride with the remainder and the liberated metal uniting with the oxygen.

1765. *The protochloride of tin* acts as an acid. It is composed of one atom of tin, and one of chlorine.

1766. *The bichloride of tin* may be obtained in the anhydrous state, by gently heating a mixture of metallic tin with the bichloride of mercury. The bichloride is a colourless liquid, very acrid to the taste. It is volatile, and when exposed to the air produces dense and suffocating fumes. It is still occasionally called by its ancient name of the *fuming liquor of Libavius*. By the addition of one-third of its weight of water, this bichloride forms a solid crystallizable hydrate, which, nevertheless, dissolves on the addition of a sufficient quantity of water.

1767. I have been enabled to form the bichloride of tin by the direct reaction of the metal with a current of chlorine, supplied by a self-regulating reservoir. (798.) An ingot, of as much as three or four ounces in weight, was introduced into a tube of about an inch in bore, previously drawn into a capillary perforation at one end. (1372, &c.) The smaller portion of the tube was curved upwards, nearly so as to form a right angle, and being inclined towards the bend, any liquid generated within the tube, had inevitably to flow into and occupy the cavity at the curvature. By these means the operator was furnished with an index by which to regulate the supply of chlorine. The apparatus being thus constructed and arranged, the tube had, at the commencement of the process, to be filled with chlorine, and the supply of this gas afterwards so regulated as to prevent any more from reaching the included metal, than it was competent to absorb. Under these circumstances, the reaction proceeded with so much energy as actually to cause the fusion of the ingot, while an ounce measure of the bichloride was soon generated.

1768. *Iodine, bromine, and fluorine* severally combine with tin in two proportions. The *perfluoride of tin* acts as a base.

1769. *The cyanides of tin* have never been isolated. Berzelius, however, states, that they exist in combination with those of iron, in which case they probably play the part of cyanobases.

#### *Of the Compounds of Tin with Sulphur and Selenium.*

1770. *The protosulphide of tin* is obtained by heating, in a crucible, three parts of finely divided tin, and two of flowers of sulphur. This sulphide is solid, crystallizable, indecomposable by heat, less fusible than tin, and acts as a sulphobase. It is composed of an atom of tin, united to an atom of sulphur.

1771. *The bisulphide of tin* I have obtained by exposing to heat in a coated glass retort, a mixture of two parts of tin, one and a half of sulphur, one of mercury, and one of sal-ammoniac.\* This compound, generally known as *aurum musivum*, or

---

\* Berzelius suggests that the mercury probably acts by bringing the tin into a state of more intimate mixture with the sulphur; and the sal-ammoniac, by carrying off, in consequence of its volatility, the heat which is evolved during the union of the sulphur with the tin, and which would otherwise be sufficient to decompose the bisulphide, were it already formed.

*mosaic gold*, is of a beautiful golden yellow. When exposed to a red heat, it is decomposed. It acts feebly as a sulphobase, and powerfully as a sulphacid. This sulphide, when spread on the surface of the cushions of electrical machines, has been found to increase their exciting power.

1772. According to Berzelius there is a third sulphide, which contains a quantity of sulphur, intermediate between those which exist in the protosulphide and the bisulphide.

1773. A gray *selenide of tin* may be procured by gently heating finely divided tin with selenium.

### *Experimental Illustrations.*

1774. Exhibition of tin and of tin foil; also of the fuming liquor of Libavius, and the process for the generation of this chloride in which an ingot of tin is made to react with chlorine. Reaction of nitric acid or nitrate of copper with tin powder. Solution of tin by chlorohydric acid, and effects of the chloride thus obtained on some other metallic solutions. Decoloration of ink and Prussian blue. Ammonia evolved by a solution of tin in dilute nitric acid.



## SECTION VIII.

### OF BISMUTH.

1775. This metal is found in nature in the metallic state; usually, however, containing a little cobalt and arsenic, and sometimes sulphur. It is also found in the state of sulphide.

1776. The only ore of bismuth which is explored, is that in which it exists in the metallic state. From this it is evolved by exposure to a wood fire, under which a hole is made to receive the melted metal.

1777. According to Berzelius, the bismuth of commerce contains iron and arsenic, and perhaps other metals. In order to purify it, it should be dissolved in nitric acid; the resulting clear solution should be mingled with water, by which a pure hydrated subnitrate of bismuth is precipitated. The precipitate being dried, is reduced by the aid of black flux\* and a gentle heat.

1778. *Properties.*—Bismuth is brittle, easily reduced to powder, and of a silvery white colour, very slightly tinged with red. It is pre-eminent for

\* The word flux is employed to signify a substance, which, being added to a mixture which is fusible, or which contains a fusible body, promotes the fusion of the whole or a part of the aggregate. Crude flux is a mixture of nitre and cream of tartar, or crude tartrate of potash. White flux is the product obtained by dehydrating the same mixture in a crucible, by a red-heat; whereas, when there is a double proportion of the bitartrate, an excess of carbon, causing the residue to be black, it receives the corresponding designation. Black flux is resorted to, where it is an object to deoxidize, as well as induce fusion. The fusion of the materials enables them more readily to move among each other, in obedience to their respective affinities, and renders it easier for metallic globules, as they are formed, to descend to the bottom of the vessel, so as to unite in one mass.

ility and regularity with which it crystallizes. Its fracture is always lustrous. Thenard alleges that, when quite pure, its crystals are cubes, and are so associated as to form a four-sided, inverted pyramid, in which they resemble stairs. Its specific gravity is 9.82. It is usually considered as unmaluable; yet Turner alleges that it may be hammered into sheets while warm. Excepting mercury and tin, it is the most fusible of metals proper. Its fusing point is  $476^{\circ}$ . It is oxidized when kept in the air; but not otherwise, unless the air be moist, in which case it is tarnished. Bismuth combines with phosphorus, and probably in a definite proportion with hydrogen. Its equivalent is 71.

8. Bismuth has of late proved to be a most valuable material for the construction of thermo-electric batteries. See my *Treatise on Electrochemistry*, page 63.

9. The reaction of sulphuric or nitric acid with bismuth, is very similar to that of the same acids with tin. Nitric acid, perhaps, reacts more readily with the former metal than with the latter; since the addition of a quantity of concentrated nitric acid to powdered bismuth, causes the evolution of so much heat as to raise the temperature of the mass to red-heat. The hydrated subnitrate of bismuth, obtained as abovementioned by adding the nitrate to water, is of a fine white colour, and has been called *white oxide of bismuth*. If chlorohydric acid be present in the solution, the white oxide assumes the form of minute scales, of a pearly lustre, called *white precipitate*. These precipitates have been used as pigments to improve the complexion, but are liable to be rendered black by sulphuric acid.

#### *Of the Compounds of Bismuth with Oxygen.*

1. There are two oxides of bismuth; one is a protoxide, consisting of one atom of metal, and one of oxygen; the other a sesquioxide, consequently, of two atoms of metal, and three of oxygen.

2. The protoxide may be obtained by heating bismuth with access of atmospheric oxygen, or by the calcination of the nitrate. When the subnitrate (magistery) of bismuth is subjected successively to a caustic alkali, and then to cold water, it forms a white hydrated protoxide of bismuth. This oxide, when anhydrous, is yellowish, fusible at a red-heat, and has a strong affinity for atmospheric oxygen, and easily reducible when heated with carbon or hydrogen. It acts as a base.

3. The sesquioxide of bismuth is obtained by boiling the protoxide in solution of the chloride of potash or soda.\* It is of a deep brown colour, and, at a temperature a little below the boiling point of mercury, is volatilized. The sesquioxide of bismuth acts neither as a base nor as an

#### *Of the Compounds of Bismuth with the Halogen Class.*

Either directly or indirectly, compounds of bismuth may be produced with the halogen bodies.

In chlorine, this metal takes fire spontaneously, forming a protochloride, from the butyraceous consistency assumed in melting, received from the old appellation of the *butter of bismuth*. This compound may also be obtained in the anhydrous state, by heating three parts of the bichloride of mercury with one of bismuth. When anhydrous, the protochloride is white, volatile, and insoluble: when subjected to water, a white insoluble oxychloride is formed.

A crystalline hydrate of the protochloride of bismuth may be formed by dissolving bismuth in aqua regia, and evaporating the solution.

---

\* Thenard, *Traité de Chimie*, 6ème ed. ii. 484.

1787. Bromides of bismuth may be obtained by heating bismuth with bromine. Iodides may be produced in like manner.

1788. Fluorine and cyanogen both combine with bismuth. The cyanide, however, is known only in a state of combination.

*Of the Compounds of Bismuth with Sulphur and Selenium.*

1789. Bismuth forms a bisulphide when heated with sulphur. At the moment when the combination takes place, a great deal of heat is evolved. It is crystalline, less fusible than bismuth, and possesses the metallic lustre and a grayish-yellow colour.

1790. When selenium is heated with bismuth, a crystalline selenide is formed, of a silvery white colour.

*Experimental Illustrations.*

1791. Bismuth and its oxide, exhibited. Its hues and habitudes with the blowpipe, compared with those of antimony, and arsenic.

SECTION IX.

OF IRON.

1792. This metal is found abundantly in nature, principally in combination with sulphur or oxygen.

1793. Large masses of iron have been observed to fall to the earth at different times, and in various countries. Besides these metallic masses, a great number of stony bodies, called meteorolites, or aërolites, have been found in like manner. In the latter, iron always exists both in the state of oxide, and in that of metallic globules. The iron in these globules, like the masses abovementioned, always contains nickel or cobalt, or both. Native metallic iron has also been found in small quantities, but does not contain nickel or cobalt. Iron is one of the most generally distributed substances in the creation, and, in the state of oxide, probably the universal colouring matter.

1794. Four species of ferruginous minerals are very abundant in nature, *magnetic oxides* and *sulphides*, and *sulphides* and *oxides* which are *non-magnetic*.

1795. Since ferruginous minerals, if not magnetic in the first instance, become so by exposure to the flame of the blowpipe, the magnet is a useful test for iron. The ores of iron consist principally of the *sesquioxide* or of a compound of this oxide with the protoxide, called the *black oxide* or *magnetic oxide*. The means of extricating iron from its ores, will be mentioned in treating of the compounds of iron with carbon, which will on that account be treated of first.

1796. *Properties.*—The mechanical properties of iron are too well known to need description. It is the most tenacious substance in nature, especially as steel, and the hardest among the malleable metals. In its native state it has a still higher pre-eminence. Few metals are more easily oxidized by the joint agency of air and moisture. In the pulverulent form, indeed, it is reduced from the sesquioxide by means of hydrogen, iron is liable to become ignited by the access of atmospheric oxygen, even after it has

pletely refrigerated. This result is more likely to ensue, if a little alumina has been previously mixed with the oxide; since this prevents the union of the particles, and thus keeps them in that state of minute division which is favourable to the success of the experiment. Iron is nearly as ductile as platinum. Its specific gravity is 7.788.

797. The equivalents of iron, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

				28
oxide,	1 atom metal, 1 atom oxygen			36
quioxide, )				
or	2 atoms „ 3 atoms „			80
oxide, )				
netic				
or	3 atoms „ 4 atoms „			
black oxide, )				116
1 atom protoxide and 1 atom sesquioxide				
trichloride,	1 atom metal, 1 atom chlorine			64
quichloride,	2 atoms „ 3 atoms „			164
disulphide,	1 atom „ 1 atom sulphur			44
trisulphide,	2 atoms „ 3 atoms „			104
quadruple,	1 atom „ 2 atoms „			60

*Of the Compounds of Iron with Carbon, Boron, Silicon, and Phosphorus.*

98. When ferruginous salts, containing carbon as a constituent, are exposed to heat without access of air, the iron and carbon are left in a state of combination in various proportions. Some of these carburets, that from the oxalate, or from the tannate or Prussian blue, for instance, are liable to take fire when exposed to the air.

99. The process of evolving iron from its ores, comes under the fourth case of affinity, in which one body in excess, combines with two others previously united. Carbon with which the ore is ignited, combines both with the oxygen and metal, converting the one into a fusible carburet, called cast iron, the other into carbonic acid. The proportion of carbon in cast iron varies from 1 part in 25, to 1 in 15. In consequence, there are four varieties of cast iron; the *white*, the *black*, the *gray*, and the *nodulated*. In the white, there is the least carbon, in the black, the most; and in the other kinds, less than in the black, and more than in the white kind.

100. It should, however, be understood, that cast iron is probably never a pure carburet. Usually, it contains silicon and manganese, and frequently magnesium and phosphorus. This last mentioned element renders the iron less malleable at a high temperature. From cast iron, the malleable metal is extricated by exposure to heat and air; by which carbon, and silicon when present, are oxidized; the one being separated as a silicate of iron with the scoria, the other escaping as carbonic acid.

101. In some cases, malleable iron is obtained directly from the ore, by means of heat and charcoal.

102. Pure malleable iron is converted into steel, by being heated in contact with coal in ovens without access of air. The process is called *cementation*. By these means, iron acquires from 1-50th to 1-120th of its weight of carbon. The bars are hardened by the operation as they are seen in commerce. Broken up and welded, they form shear steel. Fused, they constitute cast steel.

103. It would appear that silicon is a frequent, if not a necessary ingredient in steel. According to Berzelius, the presence of manganese and phosphorus is essential to the formation of good steel. Damask steel is a peculiar species, which possesses the property of exhibiting waving lines on its surface, when acted on by an acid. It is alleged by Thenard, that some experiments which have recently been made, tend to prove that this is owing to the presence of two carburets of iron; one of which is blackened by the acid, while the other resists its action. I think it more probable, that the appearance in question is owing to a mixture of iron and steel. It has, however, been ascertained that a peculiar variety of this steel called *wootz*, which comes from India, contains aluminium, and may be imitated by the introduction, into steel, of a minute portion of that metal.

1804. A silicuret, and probably a boruret of iron, may be obtained by heating iron with a mixture of charcoal and silicic or boric acid.

1805. A phosphuret of iron is produced, when phosphate of iron is heated with lampblack. It resembles iron in colour, but is brittle, and fusible by the blowpipe.

### *Of the Compounds of Iron with Oxygen.*

1806. Iron forms two oxides, a protoxide and a sesquioxide: the former, consisting of an atom of each constituent; the latter, of two atoms of metal, and three atoms of oxygen. Both these oxides act as bases.

1807. The protoxide is formed during the solution of the metal in diluted sulphuric acid. The reaction which ensues under these circumstances, is always attended by the evolution of hydrogen, arising from the decomposition of the water in combination with the acid, the oxidation of the metal, and the formation of a sulphate of the protoxide.

1808. I infer that the atom of water, which, by a union with the anhydrous acid, constitutes the aqueous sulphuric acid of Berzelius, or in other words the acid of the shops of sp. gr. 1.850, acts as an oxybase. So that the result may be ascribed to the exchange of one radical for another; an atom of iron taking the place of an atom of hydrogen. Agreeably to this view of the subject, the aqueous acid should be regarded as a sulphate of hydrogen.

1809. The protoxide of iron, forms with sulphuric acid, a green solution, which, by evaporation, yields crystals of the same colour, known in pharmacy as green vitriol, or green sulphate of iron. From a solution of this salt, the protoxide may be precipitated by an alkaline solution in the state of a white hydrate. From this hydrate the water cannot be expelled either by heat or desiccation, without causing the protoxide to acquire oxygen, either from the water in union with it, or from the air.

1810. In consequence of this avidity for oxygen, solutions of this oxide become gradually more or less solutions of the sesquioxide; exchanging their grass green colour for that of red wine.

1811. The protoxide appears to exist in chalybeate springs, and, in its nascent state, to be soluble in water; although I do not find that other chemists are aware of the fact. Its existence in them is ascribed usually to the presence of carbonic acid; but I have observed it in the water of the Yellow Springs, which gave no precipitate with lime-water.

1812. We have only to make a pile of silver coin, altered with disks of sheet iron, in a glass tumbler, supplied with water, in order to impart to the latter the property of chalybeate spring water. In the tumbler, as in those rings, the red oxide will soon be seen precipitating, and gelling, with its appropriate hue, both the liquid and the vessel.

1813. As light promotes the further oxidation and consequent precipitation of the iron, the solution of the protoxide, by the means which I have described, will be more permanent in an opaque vessel.

1814. There does not appear to be any mode in which the protoxide of iron can be isolated.

1815. The sesquioxide, or peroxide of iron, also called the red oxide from its colour, which is of a dingy blood-red, exists in nature in great abundance, forming, sometimes, large beds or masses, at other times, botryoidal, or mammillary concretions.

1816. Ochres consist of alumina, mixed with the sesquioxide of iron, either uncombined with water, or in the state of hydrate.

1817. The sesquioxide, as we have already stated, is spontaneously produced by the absorption of oxygen by the protoxide, when exposed to the air. In fact, by the addition of nitric acid to any ferruginous solution, the iron becomes more or less sesquioxidized. On the other hand, it may be partially deoxidized, and restored to the state of protoxide, by digestion with iron filings, or by the addition of protochloride of tin. Hence, the black colour of the iron gallate of iron, which, when suspended in water, constitutes common writing ink, is removed by the addition of this protochloride. It appears probable, that the iron passes to the state of oxychloride in the following way. A portion of this metal takes chlorine from another portion to form a bichloride, while the other portion abstracts oxygen from the iron, forming of course an oxide. The resulting oxide combining with the bichloride, an oxychloride is produced. In the state of protoxide, to which the iron is brought by the partial deprivation of oxygen, it forms a colourless compound with the tanno gallic acid.\*

**Protochloride of tin** is the most efficient remedy for removing ink stains, or iron stains. It is made by the reaction of chlorohydric acid with an excess of tin in ether or in tinfoil, or otherwise sufficiently comminuted. It is better to use it

1818. When a solution of the protoxide of iron is added to a solution of the chloride of gold, this metal probably relinquishes its chlorine to one portion of the iron in the protoxide. The oxygen, consequently displaced, sesquioxidizes another portion of the iron; so that metallic gold precipitates, and the chloride and oxide of iron, combining in the state of an oxychloride, remain in solution.

1819. By intense heat the acid may be expelled either from a nitrate or sulphate of iron, and the sesquioxide consequently obtained. It has been stated, in treating of sulphuric acid, that it was originally distilled from copperas or green vitriol, the sulphate of the protoxide of iron. The oxide which remains after the expulsion of the acid, has long been known under the name of *colcothar of vitriol*. The metal necessarily becomes peroxidized during this process by the partial decomposition of the acid. (771.) To render it free from all remains of acid, it should be washed with water.

1820. The protoxide and sesquioxide of iron combine in various proportions. The scales, called *finery cinder*, which fly off during the forging of incandescent iron, consist of protoxide and sesquioxide. The oxide formed by subjecting iron at a red-heat to steam, is the *black oxide*, composed of one atom of protoxide and one of sesquioxide.

1821. The native magnetic oxide of the mineralogists, is, according to Thenard, the same as that obtained when iron is oxidized by steam.

1822. The same author alleges that neither the hydrate of the protoxide nor sesquioxide are magnetic; this quality being exhibited only when the two oxides are associated in the proportion of one atom of protoxide to one of sesquioxide.

#### *Of the Reaction of Iron with Acids.*

1823. The reaction of iron with sulphuric acid when hot and concentrated, is quite analogous to that already described as taking place between that acid, and mercury, copper, lead, &c. The reaction of iron with this acid

with an equal portion of acetic acid, and the addition of its volume of water. The spot to be operated upon should be first moistened with water, to prevent the chloride from spreading unnecessarily. After the stain disappears, the remains of the solution should be well washed, as otherwise corrosion might ensue.



when dilute, has been mentioned and explained above. 1807.)

1824. In its habitudes with nitric acid, iron resembles tin and bismuth. If the acid employed be concentrated, and the iron minutely divided, the reaction is liable to become explosive.

1825. With gallic and tannic acids, as existing in the infusion of galls, the sesquioxide of iron produces a purple or black colour, in other words, ink.\* With succinic acid the sesquioxide yields a brown precipitate; with benzoic acid, an olive coloured precipitate; and with meconic and sulphocyanhydric acid, a blood-red colour.

### *Of the Compounds of Iron with the Halogen Class.*

1826. Chlorine forms with iron a protochloride and sesquichloride, which correspond in composition with the oxides.

1827. *The anhydrous protochloride* may be obtained by passing chlorohydric acid gas over iron filings heated to redness in a glass tube.

1828. *The hydrous protochloride* may be procured by the action of liquid chlorohydric acid on iron filings. The protochloride, in its anhydrous state, is of a pale green colour, astringent, crystallizable, very soluble in water, and volatilizable by heat. When exposed to the action of the air, it absorbs oxygen, and forms an oxychloride, consisting of the sesquioxide, and sesquichloride.

1829. *The hydrous sesquichloride* of iron is produced,

\* The materials for common writing ink are an infusion of galls, sometimes with the addition of a small proportion of an infusion of logwood, and green sulphate of iron, which, in its ordinary state, contains more or less of the sesquioxide of that metal. The black hue of the liquid resulting from these infusions, increases in intensity by exposure to the atmospheric oxygen, and consequent increase of the proportion of sesquioxide. Dr. Ure conceives that ink made of iron, in an inferior degree of oxidizement, penetrates the paper better than that which is made by solutions of the sesquioxide, and finally becomes equally black upon paper. There is some uncertainty respecting the composition of this liquid on account of the discordancy of opinion which has existed respecting the acids of which it consists.

It may be inferred that the acid prevailing in a fresh infusion of galls, is mainly that which was formerly called tannin, and latterly tannic acid. This acid is gradually converted into gallic acid, when the infusion in which it exists is exposed to the air. Either acid will produce ink, with ferruginous solutions, but it does not appear to me, that it is known which of the two answers the best for this purpose. I have found a beautiful blue black ink to result from the reaction of a filtered infusion of galls in cold water with finery cinder. It is too much prone to precipitate, but by agitation is always resuspended. The old practice of introducing cotton into a inkstand, removes this inconvenience in great measure. Over common ink it has these advantages, it contains no free sulphuric acid, and makes no grounds which cannot be resuspended.

when the sesquioxide of iron is exposed to the action of chlorohydric acid. It may be obtained in the anhydrous state, by heating iron filings in an excess of chlorine. Thus obtained, it is volatile and deliquescent.

1830. *Bromine and iodine* form compounds with iron, which no doubt correspond in composition with its oxides and chlorides.

1831. *There are two fluorides of iron* which act either as acids or bases.

1832. *The protocyanide of iron* is formed by exposing the cyanoferrite of ammonium, which is a compound of the cyanides of iron and ammonium, to heat in a retort. The cyanide of ammonium, which is volatile, passes over, leaving the protocyanide of iron in the form of a grayish-yellow powder. This cyanide acts as a powerful cyanacid, combining in that capacity with the cyanides of almost all the metals. It also combines with cyanhydric acid, but whether as an acid or a base, appears to me doubtful. I incline to the opinion that it acts as an acid, forming a cyanoferrite of the cyanobase of hydrogen.

1833. *The sesquicyanide of iron* is obtained by mingling a solution of the fluosilicate of the fluobase of iron with a solution of the cyanoferrite of potassium. A fluosilicate of the fluobase of potassium precipitates, and the sesquicyanide of iron remains dissolved. Its solution is of a deep brownish-yellow colour, and an astringent taste. If we attempt to obtain it in the solid form by desiccation, it is partially decomposed, and converted into Prussian blue.

1834. *Of Prussian Blue.*—When the cyanide of potassium is mingled in solution with a ferruginous salt, a precipitate ensues, well known under the name of Prussian blue, having been first accidentally discovered at Berlin. It would seem, that the perfect colour of this precipitate, both oxides of iron should be present; so that the protoxide may produce the protocyanide, and the sesquioxide the sesquicyanide. These cyanides, by their union, form the compound in question. (1830, &c.)

#### *Of the Compounds of Iron with Sulphur and Selenium.*

1835. Iron forms with sulphur a protosulphide, a sesquisulphide, and a bisulphide. Moreover, the protosulphide combines in various proportions with the bisulphide or with the metal.

1836. *Hydrated protosulphide* is alleged to be formed during the combustion which arises from triturating with moisture two parts of iron filings with one and a half of sulphur. This hydrated protosulphide is liable to absorb oxygen with a rapidity so great as to produce ignition. Owing to this property, its presence in bituminous coal beds sometimes causes them to take fire spontaneously.

1837. *Native protosulphide of iron* is of rare occurrence; but the magnetic and bisulphides are abundantly found in nature, especially the latter, which is one of the most common minerals. From its resemblance to gold, it is frequently mistaken for that metal by inexperienced observers. When intensely heated, a portion of its sulphur sublimates; and hence it is one of the sources of that important substance.

1838. *Of the bisulphide*, it is alleged by Thenard, that there are two varieties, which, though identical in composition, are dissimilar in their crystalline form and in their properties. Of these varieties, only one is susceptible of spontaneous reaction with air and moisture, and consequent conversion into a sulphate. To a similar transformation of this and other sulphides, we are indebted for the greater part of the green vitriol, or sulphate of iron, used in the arts. Beds of these minerals, in a state of decomposition, are to be met with in every country.

1839. *Sesquisulphide of iron* is produced, when the sesquioxide of this metal is exposed to a current of sulphuric acid, provided the temperature be not above 212°. At a higher temperature, a bisulphide results.

1840. *The protosulphide and bisulphide of iron*, constitute, as Thenard mentions, the mineral called magnetic pyrites. This mineral is also formed, as he alleges, when iron in a state of intense ignition is presented to sulphur, and when either the sesquisulphide or bisulphide is fused. In fact, it would seem that he considers none of the other sulphides as magnetic; although the presence of a greater proportion of iron in the protosulphide would lead us to suspect in it a greater susceptibility of magnetic influence. Berzelius, however, considers the protosulphide as magnetic.

1841. *The selenide of iron* is formed by causing the vapour of selenium to pass over iron filings heated in a glass tube. It has a metallic brilliancy, and a deep gray colour approaching to yellow.

*Experimental Illustrations.*

12. Iron, dissolved by chlorohydric and sulphuric

Red and magnetic oxide of iron, exhibited; and solutions precipitated by galls, and by cyanoferriteassium. Effects of protochloride of tin on the colour; precipitates. Ores of iron, rendered magnetic by blowpipe.



## SECTION X.

## OF ZINC.

1. This metal exists in nature in four states; in that of sulphate, silicate, and sulphide. As a silicate or carbonate, it is known in Egypt under the name of *calamine*; its sulphide is called *blende*.

From calamine or from blende, when converted into an oxide by heat, the metal is obtained by heating it with charcoal, in a crucible held in the centre of the bottom. To this a sheet iron tube is adapted, in which the zinc is conveyed in liquid globules or vapour to a vessel of water situated beneath, within which the vapour consequently condenses. The process is called distillation by descent, "*distillatio per descensum*." The metal may be purified by redistillation.

*Properties.*—Zinc is of a brilliant metallic white colour, tinged with blue of lead. Its structure is strikingly crystalline. Its specific gravity is about 6.86. Under ordinary circumstances it is not malleable, but may be laminated by rollers at a heat somewhat above that of boiling. It melts at about 680°. That it may be volatilized at a higher temperature must be evident from the process by which it is obtained as above. (1844.) By exposure to the atmosphere it is slightly oxidized, and when heated burns rapidly with intense light, the resulting oxide being volatilized in fumes. Water is rapidly decomposed when passed in the steam over ignited zinc, or when presented to it together with a due amount of sulphuric or chlorohydric acid. Zinc combines with carbon and phosphorus.

The equivalents of zinc, and of its compounds with oxygen, chlorine and sulphur, are as follows:—

Zinc,				32
oxide,	1 atom metal,	1 oxygen,		40
oxide, doubtful.				
chloride,	1	" "	1 chlorine,	68
sulphide,	1	" "	1 sulphur,	48

*Of the Compounds of Zinc with Oxygen.*

7. The protoxide of zinc is formed during the combustion of the metal in atmospheric air. From the light-

ness and flecciness of its texture, when obtained in this way, it was formerly variously called pompholix, nihil album, or lana philosophica. The protoxide may be obtained from one variety of the ore called calamine, by heating it to expel carbonic acid. To prepare it as it is presented to us in the shops, the ore is roasted, pulverized, and levigated. A better process, as I conceive, is that of collecting the woolly matter produced by the combustion of the metal. But to either of these modes I should prefer that of precipitating the oxide from the sulphate in solution, by liquid ammonia.

1848. Peroxide of zinc has been obtained by mingling bioxide of hydrogen with a dilute solution of the nitrate of this metal, as in the process for the peroxide of copper, which it resembles in many of its properties. (1706.) The protoxide usually acts as a base, though in some cases it may act feebly as an acid. The peroxide performs the part neither of a base nor of an acid.

1849. The reaction of sulphuric acid with zinc is similar to that of the same acid with iron. (1807.) When subjected to nitric acid, zinc takes all the oxygen from one portion of the acid, while the protoxide thus formed is dissolved by another portion; meanwhile the nitrogen escapes with violent effervescence. Professor Emmet has recommended the reaction of this metal with the nitric acid in nitrate of ammonia, as the means of procuring pure nitrogen.

1850. If the solution of the acetate of zinc, obtained by the reciprocal decomposition of the acetate of lead and sulphate of zinc, (522,) be clarified by subsidence or filtration, and then evaporated, the acetate of zinc may be obtained in the crystalline form. It will also be in a state of purity if the materials have been used in the equivalent proportions, or with a slight excess of the acetate of lead. Pure acetate of zinc may also be obtained by the process for forming the arbor Saturni; as in that process, after a sufficient time, the lead is completely precipitated by the zinc, which remains in solution. In this process a piece of zinc being suspended in a solution of acetate, or, preferably, nitrate of lead, and having a greater affinity for oxygen, it deoxidizes the lead. This, being thus rendered insoluble, precipitates; while the resulting oxide of zinc is seized by the acid and dissolved.

1851. The state of zinc is also obtained, agreeably to one of the formulas of the Pharmacopœias, as a tincture, in other words, in alcoholic solution, by subjecting a mixture of sulphate of zinc and acetate of potash, in equivalent proportions, to alcohol. The mixture of the salts is followed by a reciprocal decomposition, analogous to that produced by the mixture of sulphate of zinc, and acetate of lead; excepting that the resulting sulphate of lead is quite insoluble in water, and separates by precipitation; while, in the other case, both of the resulting salts, being more or less soluble in water, alcohol is employed to separate them. This liquid does not dissolve the sulphate of potash, while it readily takes up the acetate of zinc.

*Of the Compounds of Zinc with the Halogen Class.*

1852. Anhydrous chloride of zinc is formed during the combustion of zinc in chlorine. It was formerly called the *butter of zinc*, from its consistency. It is of a grayish-white colour, translucent, astringent, fusible at the temperature of boiling water, and volatilizable at a red-heat. By dissolving zinc filings in chlorohydric acid, and evaporating the solution to dryness, we may obtain this chloride in the state of hydrate.

1853. Zinc combines with iodine, fluorine, and cyanogen. The cyanide acts as an acid, the fluoride both as a base and an acid.

*Of the Compounds of Zinc with Sulphur and Selenium.*

1854. Sulphide of zinc may be obtained by heating the sulphate to whiteness with a carbonaceous paste. It is difficult to combine zinc directly with sulphur; but when the vapour of sulphur is passed over incandescent zinc, a combination takes place with a violent commotion, and the evolution of so much heat as to volatilize part of the zinc. The same result ensues when zinc filings are suddenly and intensely heated with the persulphide of potassium, or the powdered bisulphide of mercury.

1855. Sulphide of zinc is solid, yellow, tasteless, less fusible than zinc, indecomposable by heat alone, but reducible by intense ignition with charcoal. It is a powerful sulphobase.

1856. When the sulphate of zinc is decomposed at a low red-heat by hydrogen, an oxy-sulphide, or in other words a compound of the sulphide and oxide, is formed.

1857. When the vapour of selenium is passed over zinc heated to redness, the union of the two substances takes place with violence, being attended with the phenomena of active combustion. The resulting selenide is a yellow powder.

*Experimental Illustrations.*

1858. Zinc, subjected to diluted sulphuric, and diluted chlorohydric acid. Arbor Saturni, produced by it in a solution of nitrate of lead. Combustion of the metal in an incandescent crucible. Its habitudes with the blowpipe,

exhibited. Reaction of zinc filings and bisulphide of mercury; also of the melted metal with a fused nitrate.

## SECTION XI.

### OF ARSENIC.

1859. This metal is found in nature, in combination with oxygen, sulphur, and various metals. It is sold in commerce under the name of cobalt, and in the state in which it bears this name, it is full of crevices, and so much tarnished or blackened by oxidizement, both internally and externally, that it is not possible, even by a fresh fracture, to see the true colour and lustre of the metal.

1860. In order to attain this object, the cobalt (as it is absurdly named) should be coarsely pulverized, and introduced into a glass tube sealed at one end. The tube should be less than half full. Thus prepared, it should be placed within a cylinder of iron, closed at the base. The butt-end of a gun barrel will answer. The space between the iron and the glass should be filled with sand, and another gun barrel applied, so as to receive any fumes which may arise, and conduct them into a chimney. That portion of the glass tube which contains the arsenic, should be kept red-hot for about half an hour. After the apparatus is quite cool, the metal will be found in crystals of great splendour, occupying that portion of the glass tube which is next the part heated to redness.

1861. *Properties.*—Exposed before the blowpipe, arsenic is distinguished by burning before it fuses, and by emitting copious white fumes, which have the odour of garlic. These fumes are easily produced, by projecting a portion of the metal upon a hot iron, or by subjecting it in any other way to heat and air. They are evolved on a large scale during some metallurgic operations, and, after being purified by a subsequent sublimation, constitute the arsenious acid or white arsenic of the shops. This metal is extremely brittle and friable, and, when newly sublimed, has the colour and brilliancy of polished steel. It requires less heat to vaporize than to fuse it; so that it cannot be melted without the aid of a pressure greater than that of

osphere. Thenard alleges that it may be sublimed in a retort filled with nitrogen, at the temperature of  $356^{\circ}$ . Under the impression, that the nitrogen must co-operate as a solvent in this result; taking up the metal in the inner part of the retort, and depositing it in the outer part. I have ascertained that metallic arsenic, when in a glass tube immersed in melted lead, is not oxidized, unless so far as it may be oxidized; and, moreover, in the process for obtaining the arsenical ring, I have ascertained that it is formed just beyond the part of the tube which is reddened by the heat.

2. The following table gives the equivalents of arsenic, and of its compounds with oxygen, chlorine, and sulphur.

Arsenic, doubtful.	-	-	-	-	38
Arsenious acid,	2 atoms	metal,	3 atoms	oxygen,	100
Arsenic acid,	2 atoms	"	5 atoms	"	116
Arsenic chloride,	1 atom	"	1 atom	chlorine,	74
Arsenic chloride,	2 atoms	"	3 atoms	"	184
Arsenic sulphide,	1 atom	"	1 atom	sulphur,	54
Arsenic sulphide,	2 atoms	"	3 atoms	"	124
Arsenic sulphide,	2 atoms	"	5 atoms	"	156

### *Of the Compounds of Arsenic with Oxygen.*

1. According to Berzelius, the black matter which is the brilliancy of metallic arsenic on exposure to air, is a suboxide. Thenard seems inclined to consider it as a protoxide; while by other chemists it is treated as a mixture of arsenious acid and the metal; as, when heated to heat or to acids, it yields arsenious acid, and metallic arsenic. But as it appears that arsenious acid is composed of oxygen and the metal, in the ratio of three of the former to two of the latter, it would be reasonable to infer the existence of a compound consisting of three of each. Besides, it has been ascertained by Berzelius, that the exposure of arsenic to air never causes the absorption of more than eight per cent. of oxygen; and, to form arsenious acid, the metal must absorb twenty per cent. Now it seems very improbable that, under the same circumstances, one portion of the metal

should absorb thirty-two per cent. of oxygen, while another portion should absorb none.

1864. *Arsenious acid* is found in nature both in crystalline form and in that of white powder. It forms the fumes which are so copiously evolved when arsenic is ignited in the air. It is milk-white, has a rough and slightly acid taste, followed by a flavour feebly sweet. It is hardly necessary to state that it is a virulent poison. When subjected in open vessels to a low red-heat, it softens, and sublimes, in the form of a white powder, or, when the vessels are large and the operation slow, in regular octohedral crystals.

1865. *Arsenious acid* is soluble in water, but not to any great extent. Berzelius states that a saturated solution of it in boiling water, in which the deposition of crystals has commenced, contains but a twelfth or thirteenth of its weight. There is much uncertainty, and some mystery, respecting the extent of its solubility in cold water. Berzelius quotes an observation made by Fischer, that the portion employed is never entirely dissolved; and that as the ratio of the water to the acid increases, this being always in excess, the quantity dissolved lessens. Thus 80 parts of the former take up  $\frac{1}{10}$ th of its weight; 160 parts,  $\frac{1}{10}$ th; 240 parts,  $\frac{1}{10}$ th; and 1000 parts, only  $\frac{1}{11}$ th.

1866. *Arsenious acid*, when subjected in close vessels to a heat approaching to redness, fuses into a transparent glass of the specific gravity of 3.699, unchangeable in dry air, but gradually becoming white and opaque in a humid atmosphere. In the last mentioned state, it appears to be more soluble in boiling water, and to be retained in solution to a greater extent than in the transparent state. The transparent acid reddens litmus; while, by the opaque, litmus previously reddened may be restored to its original colour. These varieties of arsenious acid are, therefore, considered as isomeric. (1153.)

1867. *Of Arsenic acid*.—By digestion in aqua regia or in strong nitric acid, evaporation of the resulting solution to dryness, and subsequent ignition nearly to redness in a platinum crucible, arsenious acid acquires two additional atoms of oxygen; so that a compound is formed in which the metal is to the oxygen, in the proportion of two atoms to five. This compound is *arsenic acid*, which is solid, white, and caustic, and capable of reddening litmus.



When exposed to heat it melts into a glass; but if the heat be pushed to redness, it is decomposed into arsenious acid and oxygen gas. This is a more powerful acid, a more virulent poison, and more energetic in its affinities, than arsenious acid. Like other acids, which bear a high temperature without decomposition or volatilization, it expels, when aided by heat, the volatile acids from their combinations. It forms, with certain metallic oxides, salts which crystallize in the same form as the corresponding phosphates; whence, as I have elsewhere stated, (474,) arsenic and phosphoric acid are said to be isomorphous. Of such bodies, one may be substituted for the other in crystalline compounds, without altering the form of the resulting crystals.

1868. Arsenic acid is deliquescent, and much more soluble than arsenious acid; yet after being vitrified by heat, it does not dissolve completely at first, but deposits a white powder, which, by frequent stirring, finally dissolves. In consequence of this and some other differences in their properties, it has been supposed that the melted and unmelted arsenic acids are isomeric with regard to each other.

1869. Arsenious and arsenic acid severally combine with the metallic oxides. Arseniate of potash is formed, when arsenious acid or metallic arsenic is deflagrated with nitrate of potash. Fowler's solution, the *liquor potassæ arsenitis* of the U. S. Pharmacopœia, is made by boiling arsenious acid and carbonate of potash, of each 64 grains, with a pint of distilled water, and adding four fluidrachms of the spirit of lavender. The arsenious acid, displacing the carbonic acid, forms with the alkali an arsenite of potash. This solution produces a yellow precipitate with nitrate of silver, without the aid of ammonia, as the place of his base is supplied by the potash.

1870. The soluble arsenites and arseniates yield precipitates with solutions of copper and silver, and destroy the blue colour of the iodide of starch, by the superior affinity of iodine for arsenic. In the instance of copper and silver, an arsenite or arseniate of those metals is formed. The arsenite of copper is of an apple-green colour, and forms a pigment called Scheele's green. The arsenite of silver is yellow; the arseniate, brick-red.

1871. Sulphuric acid when cold does not react with ar-

senic; but when warm, the acid is decomposed, and arsenious acid formed.

1872. *Of nitric acid* the reaction with arsenic is similar to the reaction of sulphuric acid with the same metal; except that it takes place without the aid of heat, and that the arsenious acid which is at first produced, is finally converted into arsenic acid.

*Of the Compounds of Arsenic with the Halogen Class.*

1873. *A sesquichloride of arsenic* is obtained by the direct reaction of chlorine with arsenic, or by the distillation of this metal with the bichloride of mercury. If, in this process, the protochloride of mercury be substituted for the other, a protochloride of arsenic is generated: and by the reaction of the metal with an excess of chlorine, a perchloride results.

1874. *The sesquichloride* is a colourless, fuming liquid, of an oleaginous consistency, quite analogous, both as to the means of evolution and its properties, to the bichloride of tin, or fuming liquor of Libavius. (1766.)

1875. *Bromine and iodine* severally form compounds with arsenic, which correspond in composition with the sesquichloride.

1876. *The fluoride of arsenic* is a colourless, fuming liquid, which probably consists of two atoms of arsenic, and three of fluorine.

*Of the Compounds of Arsenic with Sulphur and Selenium.*

1877. There is scarcely any limit to the number of proportions in which arsenic and sulphur appear to be capable of combining; yet Berzelius admits the existence of but five distinct sulphides, and Thenard recognizes only three,—a protosulphide, a sesquisulphide, and a persulphide. By the union of these with various quantities of the metal, or of sulphur, all the other compounds are supposed to be produced.

1878. The proto, sesqui, and persulphide severally combine with sulphobases, as sulphacids.

1879. *The protosulphide of arsenic*, known in commerce by the name of *realgar*, may be obtained by heating a mixture of two parts of sulphur, and rather less than three and a half parts of arsenic. It is procured in the large way by distilling arsenious acid with sulphur. It is tasteless, crystallizable, less fusible than arsenic, and of an orange-red colour. When heated in close vessels it volatilizes unchanged, but if the air be admitted it is converted into arsenious and sulphurous acid. It is found native.

1880. *The sesquisulphide* is obtained by adding chlorohydric acid to a mixed solution of sulphide of potassium and arsenite of potash. The oxygen of the arsenious acid and of the potash unites with the hydrogen of the chlorohydric acid, the chlorine with the potassium, and the sulphur with the arsenic. The chloride of potassium remains in solution, while the arsenic and sulphur precipitate in the state of sesquisulphide, and in the form of beautiful yellow flocks.

1881. *The sesquisulphide* is found in nature, and is known in commerce under the name of *orpiment*. It is crystallizable. When heated gently in close vessels it melts, and if the heat be further elevated, volatilizes, and may be condensed unchanged. If the access of air be permitted during the operation, sulphurous and arsenious acid are formed.

1882. *The persulphide of arsenic* is formed by passing sulphydric acid

in a solution of arsenic acid in water. It is yellow, and resembles. It is fusible, volatilizable, and capable of reddening litmus. A selenide is produced, when arsenic is dropped into selenium, liquefied by heat. If this selenide be subjected to distillation at a perselenide is obtained.

*e Compounds of Arsenic with Phosphorus and Hydrogen.*

1 *phosphuret of arsenic* may be formed by heating phosphorus etal. It is black and brilliant.

2 *arseniuretted hydrogen*.—If in charging the self-regulating or the evolution of hydrogen, (797, &c.) an aqueous solution of acid be substituted for water, the other materials being as usual acid and zinc, arseniuretted hydrogen will be evolved with no less in that with which the evolution of the pure gas is accomplished, arsenious acid is not present.

When this gas is made to pass through a tube kept by means of a coal fire, as hot as the glass will bear, the arsenic is precipitated in metallic form, in the cooler part of the tube, just beyond the

The process above described, is decidedly preferable to any other, respects convenience and economy, but the safety of the operation

to procure this gas devoid of pure hydrogen, Soubieran recommends an alloy of equal weights of arsenic with zinc be made by subjected to strong chlorohydric acid.

Confidence is to be placed in the recommendation of the distiller above named, it follows, that by the introduction of such to the self-regulating reservoir, substituting strong chlorohydric sulphuric acid, there would be a supply of pure arseniuretted hydrogen at command.

Arseniuretted hydrogen is highly inflammable, in common with other compounds of hydrogen. It is extremely deleterious to the operator when liberated in quantities too small to be immediately perceived. It is productive of nausea and vomiting, sometimes of purging. As palliatives of these symptoms Soubieran recommends warm tea, and sulphydric acid gas.

In generating this gas for illustration, by the apparatus employed in the philosophical candle, (805,) I inadvertently inhaled enough to procure a transient indisposition. Gehlen, a respectable German chemist, died by a similar inadvertency. This gas is the more insidious, as it is not warned of its presence by the fetidity of its odour, as in the combinations of hydrogen with sulphur and phosphorus, and arsenic. A ten-thousandth part of this gas may be detected in a mixture, by the metallic pellicle which it causes upon a solution of chloride of platinum.

1 of turpentine appears to form a crystalline compound, by re-arseniuretted hydrogen.

A solid compound of arsenic with hydrogen has been made, by an alloy of potassium and arsenic to water; and likewise by the action of water by the Voltaic series, one of the wires, employed for terminating in a piece of arsenic immersed in that liquid.

*Experimental Illustrations.*

1894. Appearance and habitudes of arsenic, in its metallic and crystalline form, contrasted with those of zinc, antimony, and bismuth. Arsenious acid and its solutions, exhibited; also, Fowler's solution, or solution of arsenite of potash. Arsenious and arsenic acid, in solution, added to large vessels of clear water, and detected by sulphydric acid, or by ammoniacal nitrate of silver or copper. Same acids precipitated by lime-water. Exhibition of Scheele's green, or arsenite of copper. Combustion of arseniuretted hydrogen, displayed.

*Of the Means of detecting Arsenic, in Cases where poisoning by Arsenical Compounds is suspected.*

1895. As respects arsenic, the most important object of attention is the means of detecting this metal, in cases in which an arsenical compound may be used as a poison.

1896. The first steps are of course directed to the collection and preservation of all the matter which may have come from the patient in vomiting, or which may be obtained by opening the stomach. As the combination of this metallic poison usually administered is arsenious acid in the pulverulent form, all the matter collected and the surface of the stomach should be rigidly examined, in order to detect any particles which may remain in that state. Berzelius counsels us especially to scrutinize those spots in the stomach which appear to have been inflamed, in order to ascertain whether any particles of the poison are lodged in them.

1897. In the next place, the whole mass, collected and preserved as above advised, should be thrown into water, which, while stirred to cause the suspension in it of the lighter portions of the matter, should be poured off, together with that lighter matter from the heavier subsiding portion. The liquid thus separated should be filtered; and both the resulting filtered solution, and the heavier matter which may have sunk to the bottom of the vessel, should be evaporated to dryness in an appropriate oven, or in a vessel kept hot by boiling water. The whole being quite

7, it should be introduced into a glass or porcelain vessel; and, adding a sufficient quantity of strong nitric acid cover the mass, it should be subjected to a heat adequate cause a brisk reaction. This should, if necessary, be sustained by further additions of the acid, until there is no longer any organic matter undecomposed.

1898. As nitric acid can have no other effect upon arsenic than that of converting it into arsenic acid, in which state it is less volatile than in any other; this process tends at the same time to annihilate the organic impurities, and secure the metal. Thus the matter to be assayed is much diminished in bulk, and if it contain arsenic must be treated as arsenic acid, which is more soluble than arsenious acid. Hence, if the dry mass be digested with water, a solution will be obtained, which, being filtered, may be precipitated by lime-water. The arseniate of lime which precipitates, being dried, should be mingled with about one-fourth of its weight of powdered charcoal, and introduced into a glass tube, sealed at one end. The mixture having been made to settle down to the sealed end within narrow limits as possible, a little cotton wick must be fastened to the end of a wire, by twisting the wire so as to form one end into an eye, and passing the wick through the eye, and winding it about the end of the wire, until a plug of cotton be made just large enough to slide in the tube like a piston. For greater security, the wick may be wound about the wire, so that one end may be held in the hand. By means of the piston, thus formed, the portion of the tube, not occupied by the mixture, may be wiped clean. The tube should now be subjected to the flame of a spirit lamp, the piston being retained in it, as near the mixture as it can be without being injured by the heat. The heat should be applied at first to the anterior part of the mass, proceeding to the posterior part afterwards; and as soon as the whole ceases to give out aqueous vapour, the piston should be passed quickly down, so as to wipe away the moisture condensed, together with any accompanying foulness. The piston being again beyond the reach of the heat, the part of the tube containing the mixture should, by the aid of a blowpipe, be exposed to a temperature as high as the glass will bear. If there be arsenic in the mixture, it will now appear in a bright metallic ring, situated beyond that part of the tube which was heated red-

hot. On cutting the tube at the part where the ring appears, and heating it by a spirit lamp, the alliaceous smell of arsenic will be perceived, if this metal be present; and the same smell will be experienced on igniting the cotton of the piston above mentioned.

1899. The process thus described for obtaining the arsenical ring is nearly the same as that which I employed in the analysis of some matter sent to me from Westchester by Dr. Thomas; having been obtained from the stomach of a woman poisoned by her husband. I afterwards repeated it successfully at Westchester, in presence of Dr. Thomas and another physician; and upon their evidence of the result so obtained, the murderer was convicted. Before his execution he confessed himself to be guilty.

1900. Where no arsenic can be detected in the contents of the stomach, it may be found in the membranes, or coats. Hence, in making the examination for arsenic, the stomach should be boiled in nitric acid, until all the organic matter is destroyed.

1901. Very minute quantities of arsenic may be detected by the aid of silver or copper in solution. With silver, arsenic acid gives a brick-red, arsenious acid, a yellow precipitate. With copper, arsenious acid produces a very striking green precipitate of arsenite of copper, called Scheele's green. Sulphydric acid gas produces, with either acid, a yellow precipitate of sulphide of arsenic. As these results are precarious, and liable to be produced by other causes, they should not be considered as conclusive evidence.

1902. In the case of the murder above mentioned, I found that the arsenic acid, as procured from the contents of the stomach, would not assume the appropriate hue in precipitating with silver, whether before or after its union with lime. Instead of a brick-red, it was of a muddy colour. By Dr. Feutchwanger, who was present during many of my experiments, this was ascribed, correctly, as I believe, to phosphoric acid. It has been stated, that it is difficult to separate these acids when associated, from their isomorphism, or, in other words, crystallizing in the same form. (474.)

1903. By simple affinity, neither arsenious nor arsenic acid can be precipitated by the soluble salts of silver or

er. Hence an alkali must be present, either in union with the arsenical acids, or with the metallic salt. This is attained conveniently, by the addition of ammoniacal nitrate of silver or copper; as, with either of those salts, that alkali forms a soluble ammoniacal nitrate.

14. A great improvement in our means of detecting arsenic has been introduced by Marsh, of London. It has been mentioned, (1885,) that if in the process for evolving hydrogen by a self-regulating reservoir, an aqueous solution of arsenious acid be substituted for pure water, the trials and manipulation being otherwise the same, instead of pure hydrogen, arseniuretted hydrogen will be generated. From the observations of the ingenious mechanician above named, it appears, that if any mixture containing arsenic be added to water and acid, used in an analogous miniature apparatus, the nascent hydrogen will combine with the arsenic, however minute the proportion. Consequently, a jet of the gas when inflamed, by its hue, and odour, and still more when allowed to play upon the surface of a piece of porcelain or glass, will demonstrate the presence of arsenic. In this last mentioned case, a black stain will be made, consisting of concentric circles, of which that which is central will have the metallic hue of an arsenical ring, especially when examined through the

15. The great objection to this process, as it came into the hands of Marsh is, that when the proportion of arsenic is very small, the whole may escape before the detector may be enabled to detect it. Hence, it would be preferable to resort to the expedient recommended by Liebig, of passing it through a tube heated by a Bunsen burner (1886); or to pass all the gas generated through a liquid competent to effect a complete absorption of arsenic. For this purpose a solution of corrosive sublimate might answer. (1891.)

### *Experimental Illustrations.*

16. Small portions of arsenious acid, or of the arsenic of lime, mingled with powdered charcoal, and subjected to heat in a glass tube. Arsenical ring, produced and exhibited.

1907. Self-regulating reservoir of hydrogen, charged with an aqueous solution of arsenious acid, sulphuric acid, and zinc. (796, &c.) Deposition produced by the flame upon glass, mica, or porcelain. Gas passed through a glass tube, reddened by a lamp, or gas flame, deposits metallic arsenic in a film resembling in appearance the arsenical ring.

## SECTION XII.

### OF ANTIMONY.

1908. Antimony sometimes occurs in nature in the metallic state and in that of oxide, also abundantly as a sulphide. It is in fact to the sulphide that the name of antimony is given in commerce, the metal being designated as the *regulus* of antimony.

1909. The ores of this metal had been known for a long time; but for its extraction from them, the world is indebted to Basil Valentine, who lived towards the close of the fifteenth century. Since that period, from its utility in medicine, it has been eminently an object of investigation.

1910. Metallic antimony may be obtained by mingling the sulphide with two-thirds of its weight of bitartrate of potash, and one-third of its weight of nitre, and deflagrating the mixture in a red-hot crucible. The oxygen of the nitre converts the sulphur into sulphurous acid, which escapes; while the alkali of both the salts operates as a flux, or in other words promotes the fusion of the mass. The carbon of the tartaric acid counteracts the oxidizement of the metal.

1911. Charcoal, intimately intermingled with carbonate of potash or soda, may be used instead of the bitartrate.

1912. Antimony thus obtained is not quite pure. To render it so it may be dissolved in aqua regia, precipitated in the state of oxychloride by water, and revived by ignition with bitartrate of potash.

1913. *Properties.*—Antimony is so brittle as to be easily pulverized. It displays a crystalline structure, and may be crystallized by the process resorted to in the case of sulphur. (750.) When quite pure and newly fractured, it is of a silver-white colour, and very brilliant. If it be rubbed between the fingers, they acquire a perceptible odour. Its specific gravity is 6.7. It fuses a little below a red-heat. When thrown in a state of fusion upon a board, it produces a beautiful effect, being dispersed into a multitude of ignited globules, which emit copious fumes of oxide, and leave their traces upon the board. The temperature of the globules seems to be supported by their own combustion.

1914. A single globule of the metal, being brought to a state of ignition by the blowpipe flame upon a piece of charcoal, if held, after operation of the blowpipe is discontinued, in a current of air, such as exists usually at an aperture in a flue, will, in consequence of the heat arising from its union with the atmospheric oxygen, continue at a bright red-heat until nearly consumed.

1915. According to Berzelius, the purity of antimony is indicated by a



whiteness, and a granular or fine lamellar texture; whereas the metal does not excel tin in whiteness, and is coarsely lamellar, almost insusceptible of cleavage. It appears to me, that the differences here referred to, are dependent, as in other cases, on slowness or quickness of cooling. A button which was granular when taken from a crucible refrigerated by fusion in an iron mortar in which it was prevented from cooling by proximity to a fire, acquired a lamellar texture. Bad antimony looks like hornblende rock when broken, as to its crystalline texture, cannot be fused into a globule as liquid or pure. It will not answer as for the experiment of throwing on the board, as the pure metal.

3. The equivalents of antimony, and of its compounds with oxygen, hydrogen, and sulphur, are as follows:—

Antimony,	-	-	-	-	-	-	-	64
Oxide,	2	atoms metal,	3	oxygen,	-	-	-	152
Antimonious acid,	2	"	"	4	"	-	-	160
Antimonic acid,	2	"	"	5	"	-	-	168
Chloride,	2	"	"	3	chlorine,	-	-	236
Sulphide,	2	"	"	4	"	-	-	272
Oxide,	2	"	"	5	"	-	-	308
Sulphide,	2	"	"	3	sulphur,	-	-	176
Sulphide,	2	"	"	4	"	-	-	192
Sulphide,	2	"	"	5	"	-	-	208

### *Of the Sesquioxide of Antimony.*

17. *Sesquioxide of antimony* may be obtained by exposing the metal to heat with access of air; by moderately heating the sulphide; or by subjecting the sesquichloride to water, in which case a powder precipitates, called *powder of Algaroth*, from the name of the physician who recommended it to public attention. This powder, when digested in water, forms an *oxychloride*, by digestion with the carbonate of soda, is converted into the sesquioxide. It may also be obtained by the reaction of the metal with diluted nitric acid, afterwards repeatedly digesting the resulting subsalt in water, until this liquid no longer reddens litmus. In the form in which the sesquioxide is obtained by heat and water, it received formerly the name of *argentine flowers of antimony*. When obtained from the oxychloride, the sesquioxide has a tinge of gray. If the sesquioxide, as produced by the last mentioned method, be heated, it takes a red color and is converted into antimonious acid.

18. Sulphuric acid, when cold or diluted, does not react with antimony, but, when warm and concentrated, is readily decomposed, evolving sulphurous acid, and forming the sesquioxide of the metal, with which the undecomposed acid combines. By water the acid may be for the

most part removed from this sulphate, so as to cause an excess of oxide so great as to render it competent the production of tartar emetic, by digestion with the tartrate of potash. In this case, the excess of oxide in the sulphate, and the excess of acid in the bitartrate, unite, converting the latter salt into the double tartrate of potash and antimony, or tartar emetic.

1919. *The sesquioxide* acts feebly both as an acid and base. Combined with bitartrate of potash, it constitutes tartar emetic, and is the only compound of antimony with oxygen, which is considered as medicinal.\*

1920. Tartar emetic may be considered as consisting

Two equivalents of tartaric acid,	$66 \times 2 = 132$
One of sesquioxide of antimony,	108
One of potash,	
Two of water,	$9 \times 2 = 18$

*Of the Compounds of Antimony with Oxygen, of inferior importance medicinally.*

1921. *Antimonious acid* is generated by digesting antimony in nitric acid, evaporating the liquid to dryness, and calcining the residue; or, thoroughly roasting the sulphide of antimony with access of air. Antimonious acid is white, tasteless, infusible, fixed, indecomposable by heat, and insoluble in water.

1922. When nitric acid is added to a solution of the antimonious potash, the antimonious acid is precipitated in the state of hydrate. In this state it reddens litmus paper.

1923. *Anhydrous antimonious acid* is obtained by subjecting the oxychloride to the action of nitric acid, and afterwards exposing the resulting mass to a temperature of  $500^{\circ}$  or  $600^{\circ}$ , to expel any excess of this acid. By flagrating the metal with four times its weight of nitre, dissolving in water the resulting mass, and afterwards adding nitric acid, which combines with the alkali, *hydrous antimonious acid* is also procured.

1924. Anhydrous antimonious acid is yellow, tasteless, and insoluble in water. When hydrous, it is white, and has the property of reddening litmus.

1925. Just at the moment when certain antimonites and antimonates subjected to a low red-heat, lose their water of crystallization, they give to a transient light, as vivid as would result from a true combustion.

\* In the last edition of this work, I quoted, on the subject of tartar emetic, an article previously published by Dr. Bache, in the American Cyclopaedia of Practical Medicine. This article I shall not introduce into this edition, because the information which it comprises, has been given in the United States' Dispensatory, to which we owe to my friend abovementioned, and to my colleague, Dr. Wood. I presume that of this Dispensatory, every matriculant of our university will be provided with a copy, as it appears to me to be of itself equivalent to a choice library of our medical knowledge.

they enter in  $\alpha$  no change in weight. Their colour is rendered brighter, and they become less susceptible of decomposition by acids. This result occurs especially with the antimonates of copper, cobalt, and zinc.

1926. The reaction of diluted nitric acid with antimony, is quite analogous to that already described in the case of bismuth. According to Berzelius, a subnitrate results, which may be decomposed by water as already stated, and converted into a hydrated sesquioxide. But Thenard informs us that, if this metal be subjected to nitric acid, it is converted into hydrous antimonious acid (*acide antimonieux blanc et hydraté*). Possibly the difference may arise from the acid being in one case concentrated, in the other dilute.

### *Of the Compounds of Antimony with the Halogen Class.*

1927. *Sesquichloride of antimony* may be obtained, as Thenard alleges, by distilling the metal with the bichloride of mercury; also by the reaction of aqua regia with metallic antimony, and subsequent distillation of the resulting liquid, collecting the product in a fresh receiver when it becomes oleaginous in its consistency. He recommends as preferable, however, the action of chlorohydric acid on the sesquisulphide with heat, allowing the sulphydric acid gas to escape into the fire. The resulting liquid is to be decanted, and concentrated by heat in a retort, until it acquires an oleaginous consistency.

1928. The sesquichloride has been designated as the *butter of antimony*. It is white, semitransparent, very caustic, fusible below a boiling heat, and crystallizable in tetrahedrons by refrigeration. It is volatile at a heat below redness, and deliquescent, so as to be liquefied by exposure to air. It has already been mentioned, that by subjecting this chloride to copious affusions of water, (eight times its weight, according to Thenard) an oxychloride results, formerly called the powder of Algaroth.

1929. *Bichloride of antimony*, agreeably to the last mentioned author, exists only in combination with chlorohydric acid.

1930. *Perchloride of antimony* is formed by the combustion of the metal in chlorine. It is a yellow liquid, sending forth thick fumes into the air, with a strong and disagreeable smell. It attracts moisture, and is, in consequence, at first converted into a white crystalline mass, but afterwards liquefied by a further accession of humidity. Yet by exposure to a large quantity of water with heat, it is decomposed, and deposits hydrous antimonious acid. This process is recommended as the best for obtaining this compound.

### *Of the Compounds of Antimony with Sulphur and Selenium.*

1931. It has been stated that antimony is procured principally from the native sesquisulphide, which is found in the shops under the name of *antimony*, the metal being distinguished as the *regulus*.

1932. *Sesquisulphide of antimony* may be formed from its ingredients, by heating the metal in a state of division with sulphur. It is more fusible than metallic antimony, is crystalline in texture, has a metallic lustre, and a bluish-gray colour. It may act either as a sulphacid, or as a sulphobase. With the sulphides of the alkalifiable metals it forms compounds which may be designated as hyposulphantimonites.

1933. The sesquisulphide and sesquioxide of antimony enter into combination with each other in different proportions, forming compounds which

must be called oxysulphides, consistently with the nomenclature adopted in the case of the analogous compounds of oxides with chlorides.

1934. When the sesquisulphide of antimony is roasted, in other words exposed to heat with access of air, it becomes more or less oxidized, according to the duration of the exposure, the degree of heat, and the supply of air. If, after the roasting has continued for some time, the temperature be raised so as to fuse the mass, a vitreous compound will result, the composition of which will vary according to the ratio of the oxide to the sulphide, at the time of effecting the fusion. According to Thomson, when the ratio of the former to the latter is as five to one, the compound has the name of *crocus of antimony*; when the ratio is as three to one, it has been called *liver of antimony*. This name, however, is given by Berzelius to a compound of the sulphides of antimony, with the sulphide of potassium or sulphide of sodium.

1935. If the sulphide of antimony, instead of being poured out as soon as it is melted, be kept for a great length of time in a state of fusion in an earthen crucible, it derives a portion of oxide of iron and silicic acid from the crucible, and thus forms a transparent mass of a yellow-hyacinth colour, commonly called the *glass of antimony*. This glass, according to Thenard, is a mixture of oxysulphide of antimony, with the silicates of antimony and iron.

1936. By the reaction of the sesquisulphide of antimony with the alkalis, either caustic or carbonated, and either in the wet or dry way, a complicated reaction ensues, by which the antimony of the sulphide is more or less oxidized, the metal of the alkali more or less sulphurized; while the residual sulphide of antimony, acting as a sulphacid, combines more or less with the resulting sulphobase of the alkalifiable metal.

1937. The extent to which the sesquisulphide, in the resulting sulphosalt, can be retained by the sulphobase in an aqueous solution, appears dependent upon temperature. Hence, whether the sulphosalt be produced in the dry way and dissolved in hot water, or be generated by boiling the ingredients in this liquid, the sesquisulphide precipitates by refrigeration.

1938. The precipitate thus obtained, under the name of *kermes mineral*, was so much in vogue in France, about a century ago, as to induce the government of that country to purchase from a surgeon of the name of La Ligerie, the art of preparing it.

1939. Thenard alleges that it appears from the analysis of Henry, Jr., that the composition of kermes varies according to the process employed for its production. When prepared by boiling the sesquisulphide in a solution of *carbonate* of potash or soda, kermes may be considered as a hydrated oxysulphide; but when procured by boiling the sesquisulphide in a solution of *caustic* potash or soda, or by *fusion* with them or their carbonates, and subsequent solution in hot water, it is a hydrated sesquisulphide, containing very little if any oxide. As obtained by precipitation from tartar emetic by sulphydric acid, it is a pure hydrated sesquisulphide. After the kermes has precipitated, a portion of the sesquisulphide still remains in union with the sulphobase. Hence, on the addition of an acid, a further precipitation takes place, both of the sesquisulphide of antimony, and the sulphur of the sulphobase; and these, either by combination or mixture, constitute the *golden sulphur of antimony*, another well known pharmaceutical preparation.

1940. According to the analysis of Henry, Jr., as quoted by Thenard,

composition of kermes, when obtained in the wet way by carbonate of is as follows:

Sesquisulphide of antimony,	-	-	62.5
Sesquioxide of antimony,	-	-	27.4
Water,	-	-	10
Soda,	-	-	a trace.

41. Upon the whole it is inferred that the sesquisulphide, in precipitated by refrigeration as abovementioned, combines with water in all cases; but when the process is conducted in the wet way by means of a caustic alkaline solution, the precipitating hydrated sesquisulphide combines with the sesquioxide, forming an oxysulphide. The presence of carbonic acid in union with the alkali is requisite, in order to enable the menstruum to dissolve while hot, a double carbonate of the alkali and sesquisulphide. The latter, being thus taken up by the aid of heat, subsequently, on the cessation of the refrigeration and its affinity for the hydrated sesquisulphide, precipitates in combination with this sulphide, as already mentioned.

42. The officinal preparation, called *precipitated sulphuret of antimony*, is obtained by adding diluted sulphuric acid to a solution of the sesquisulphide of antimony in a hot solution of caustic potash. A precipitate results which may be considered as a mixture of kermes mineral and golden sulphide of antimony.

43. *Bisulphide of antimony* is obtained, according to Thomson, by passing antimonious acid in chlorohydric acid, and subjecting the result to sulphydric acid. I infer that four atoms of chlorohydric acid, acting on two atoms of antimony, in union with four atoms of oxygen, will produce a bichloride, and that this will be converted into a bisulphide by action with the sulphydric acid.

44. The bisulphide, being resolvable into the sesquisulphide and sulphur by heat, cannot be produced by the fusion of its constituents. It is of orange-red colour, and acts as a sulphacid.

45. *Persulphide of antimony* is obtained by passing sulphydric acid through a diluted solution of the perchloride of this metal, to which tartaric acid has previously been added. Its colour resembles that of the bisulphide, but is somewhat paler.

46. The selenide of antimony is obtained by heating this metal with selenium. Like the sulphide, it is capable of entering into combination with acids.

### *Experimental Illustrations.*

47. Antimony and its sulphide, exhibited, and exposed to the blowpipe: also, the crystals and solution of tartaric acid. Kermes mineral, golden sulphur, and precipitated sulphuret of antimony, exhibited. Antimony, subjected to the action of acids. Kermes mineral, precipitated from a solution of antimony by sulphydric acid.

## SECTION XIII.

## OF METALS PROPER OF MINOR IMPORTANCE.

## OF PALLADIUM.

1948. Besides iron, copper, and lead, four metals, palladium, rhodium, iridium, and osmium, are found in union with, or accompanying the native grains of platinum, as imported from South America. Accordingly, if a portion of that assemblage of metallic particles, of which the native grains of platinum above mentioned form the principal part, be digested in aqua regia, the platinum, together with the palladium, rhodium, copper, and lead, will be dissolved; while a black powder will be left, consisting of osmium and iridium in combination with each other.

1949. The platinum having been precipitated from this solution (1857) by the chloride of ammonium, any palladium which it may contain, with all of the other noble metals which may be present, may be precipitated by a bright plate of zinc. The resulting precipitate, after being digested with chlorohydric acid and washed with water, should be redissolved in aqua regia. Any excess of acid should be neutralized by carbonate of soda. From the neutralized solution the palladium may be thrown down by a solution of bicyanide of mercury which yields its cyanogen to the palladium. An insoluble cyanide of palladium, being thus formed, precipitates. By the aid of heat this precipitate is decomposed, the cyanogen is expelled, and the metal is isolated.

1950. Mr. Cloud, of the United States' mint, found this metal in a native alloy of gold which was brought from Brazil.

1951. The colour of palladium appears to me to have a minute degree of tendency towards the rosy hue of bismuth, not being quite so pale as platinum, which it otherwise much resembles in appearance. It is however more fusible, rather harder, and more elastic. Its specific gravity, also, is much less, being about 11.5. It is malleable and ductile, and insusceptible of oxidizement by heat and air.

## OF RHODIUM.

1952. After the palladium has been precipitated, the solution contains the chloracids of rhodium, mercury, and several other metals, united with the chloride (or chlorobase) of sodium, resulting from the carbonate of soda, employed as abovementioned to neutralize the excess of acid. There is likewise present a portion of the undecomposed bicyanide of mercury. Under these circumstances, chlorohydric acid must be added, in order to convert this bycyanide into a bichloride, and the solution afterwards must be evaporated to dryness. The resulting mass should then be washed with alcohol, which dissolves all the chlorosalts of sodium present, except the chlorrhodate. Rhodium is obtained from this by heating it in a current of hydrogen, which removes the chlorine combined with the metal the chloride of sodium being removed by water.

1953. *Rhodium*, according to Berzelius, cannot be fused, except by subjecting it, when in the state of a sulphide or arseniuret, to an intense heat. After fusion, it resembles platinum in appearance. Its salts are generally either red or yellow. It is named from its chloride, which is rose-red.

## OF IRIDIUM.

954. When the black powder, consisting of the osmiuret of iridium, remains as above stated, after we have subjected the crude grains of iridium to aqua regia, is heated with soda, an osmiate of soda is formed, which may be removed by dissolving it in water. The remaining mass is then treated with aqua regia, in which the iridium, converted into a chloride, dissolves. By repeating this process, the whole is finally converted into solutions of chloride of iridium, and of osmiate of soda.

955. From the former, crystals of the chloride of iridium may be obtained by evaporation, which, on exposure to a strong heat, yield metallic iridium.

956. *Iridium* resembles platinum in appearance, and is probably, according to Thomson, the heaviest of the metals. When heated in contact with air nearly to redness it is oxidized, but on the application of a lower temperature it is again restored to the metallic state. Thenard, however, states, that iridium which has been subjected to a strong heat, is absolutely insusceptible of oxidization by the air at any temperature.

957. Iridium is said to be the most refractory of the metals, having never been fused until it was placed between the poles of Children's large galvanic battery. It was then converted into a globule, possessing metallic tenacity and lustre.

## OF OSMIUM.

958. Osmic acid may be obtained by distilling the solution of osmiate of soda, procured as above described, with nitric acid at a gentle heat. The osmic acid passes over, and may afterwards be reduced by the addition of chlorohydric acid and mercury. It is, however, alloyed with mercury, and mingled with the chloride of this metal. These may be sublimed by a gentle heat, leaving pure metallic osmium.

959. *Osmium* obtained in this way, is of a grayish-black colour; but a portion of the volatilized oxide may be made to pass with a current of hydrogen through a glass tube, the osmium is deposited in the form of a ring of metallic brilliancy, and of a white colour. It is so difficult to fuse in close vessels, and so liable to be volatilized when heated in the air, that it has never been obtained in powder, or in minute friable masses. Its volatility in the air arises from its great susceptibility of oxidization, and the volatility of its oxide, the fumes of which are pungent.

## OF NICKEL.

960. A mineral had been known to the German miners by the name *Kupfer nickel*, or false copper. About the middle of the last century, Cronstedt alleged the existence, in this mineral, of a peculiar metal. Nevertheless, the metal, thus indicated, was considered by many chemists as an alloy of copper with iron. About 1775, Bergmann confirmed, by an analysis, the allegation of Cronstedt.

961. *Kupfer nickel* is principally an arseniuret of nickel, but contains, also, sulphur, iron, cobalt, and copper. Nickel is extricated from it by a tedious and intricate process.

962. *Nickel* is of a white colour, difficult of fusion, malleable and not easily oxidized by the air. It is so susceptible of the magnetic influence that a permanent magnet may be made of it. If sufficiently abundant, nickel would be very valuable in the arts. A white alloy of this metal with cop-

per, had long been known in China, under the name of packfong. Of late this alloy has been brought into use in Europe, under the name of argente or German silver. It serves for pencil cases and many analogous uses nearly as well as silver. It combines with oxygen, chlorine, iodine, cyanogen, sulphur, and the metals. Its oxides are soluble in the acids, and in their habitudes are much like those of copper. The solubility of its protoxide in caustic ammonia, is an important means of separating nickel from its alloys.

#### OF CADMIUM.

1963. This metal has been derived only from the ores of zinc. During the reduction of calamine, a substance sublimes which yields from 12 to 20 per cent. of cadmium.

1964. A solution of the ore in sulphuric acid, being impregnated with sulphydric acid, the cadmium precipitates in the state of sulphide, mixed with a little sulphide of zinc, and sometimes with sulphide of copper. When these sulphides are exposed to chlorohydric acid, the sulphur unites with the hydrogen of the acid and escapes, and they are converted into chlorides. Carbonate of ammonia being added to the resulting solution of cadmium and zinc, a carbonate of cadmium is alone precipitated. From this, the metal may be obtained by means of heat and charcoal.

1965. *Cadmium* is almost as white as tin, is without odour or taste, very brilliant, and susceptible of a fine polish. It is crystallizable, malleable, and ductile, and so soft as to yield easily to a file or knife. Its specific gravity is 8.6 nearly. It is too scarce to be usefully applied. It fuses and volatilizes at a very low temperature.

#### OF CHROMIUM.

1966. This metal is found in nature only in the state of an acid and of an oxide, generally united with lead or iron, though in some instances pure. It was in the native chromate of lead, found usually in crystals which rival the ruby in colour, that this metal was discovered by Vauquelin. A compound of the sesquioxides of chromium and iron, called incorrectly chromate of iron, is found plentifully in this country. The sesquioxide of chromium, when intensely heated with charcoal, is reduced, but not without great difficulty.

1967. The presence of chromium in a mineral may be detected by the fusion of a minute portion before the blowpipe with borax, or preferably, with the ammoniacal phosphate of soda. In this way, a globule of a beautiful emerald green results, which preserves its colour either in the oxidizing, or reducing flame. By these characteristics it may be distinguished from copper or uranium; since uranium communicates a green hue only in the reducing flame, copper only in the oxidizing flame.

1968. *Chromium* is a hard, brittle metal, of a grayish-white colour, and very difficult to fuse. Its specific gravity is 5.9. Its equivalent is 28. It forms with oxygen a sesquioxide and an acid. The compound, heretofore considered as a deutoxide, proves to be a mixture of sesquioxide and chromic acid.

1969. *The sesquioxide of chromium* is easily obtained by exposing the chromate of mercury to heat, by which the mercurial oxide and a portion of the oxygen of the acid are expelled, while the sesquioxide remains in the form of a grass-green powder. It may also be obtained in the state of hydrate, by mixing solutions of the bichromate of potash, and persulphate



sium. This sesquioxide is of a beautiful green colour, which it communicates to some of its compounds, being in fact the colouring matter of emerald. It appears to act both as an acid and a base.

It is in common with zirconia and oxide of titanium, the sesquioxide of chromium, when obtained from the hydrate by expelling the water by a heat, becomes incandescent at a certain elevation of temperature, in which it is altogether unaccountable. At the same time it loses its power of solubility in acids which it before possessed.

*Chromic acid* may be procured by the following process:—Let parts of the chromate of lead be mixed with three parts of fluoride of calcium, both finely pulverized. Then let five parts of sulphuric acid, dephlegmated as far as possible by boiling, be added, and let the whole be heated in a leaded or platinum alembic at a gentle heat. A red gas is developed, producing in the air yellow fumes. This red gas is a sesquioxide of chromium, which, on being passed into water, is converted into chromic and chromic acids. The former may be expelled by evaporation, leaving chromic acid remaining in a state of purity.

If, instead of causing the gaseous fluoride of chromium to enter the water, it be conducted by means of a tube into a receptacle of platinum, with moistened paper, and having a small quantity of water at the end, the gas will be decomposed by the aqueous vapour, mingled with the gas of the vessel, and will deposit first about the mouth of the tube, and afterwards throughout the vessel, a flocky vegetation, consisting of ruby-crystals of chromic acid.

*Chromic acid* is solid, soluble in water, and capable of reddening

It is decomposed by heat, and by most substances which possess affinity for oxygen. It possesses an acid and astringent taste, and a red colour, which it communicates to some of its compounds, as noticed in the case of native chromate of lead. It forms striking and insoluble precipitates with various metals. That which it produces with iron is of a splendid orange-yellow, and is much used as a pigment. The streak left by the red crystals above described, when rubbed on a hard surface, is likewise orange-yellow; and the same change ensues on pulverization. The bichromate of potash is poisonous, and no other acid and its compounds are generally poisons. *Chromic acid* stains upon the skin which cannot be removed by water, unless it be washed with an alkali. Where there is any abrasion of the cuticle, the presence of chromic acid will induce a painful ulcer. Hence the sores to which dyers are exposed who employ bichromate of potash as a dye-stuff. These sores are even alleged to arise even from exposure to the vapours or fumes of chromic acid. When received into the stomach, chromic acid is a virulent

Dr. Ducatel informs us of the case of a labourer who died in five days after drawing into his mouth from a syphon, a solution of bichromate of potash; although he was under the impression that, by spitting, he had been taking it into his stomach.

Dr. Ducatel suggests an alkaline solution as the best antidote for this poison; as he ascribes its activity mainly to the excess of acid. An instance of a criminal prosecution for poisoning by this bichromate, is mentioned, which failed from that ignorance of its deleterious properties which Dr. Ducatel's communication must tend to correct.\*

## OF COBALT.

1975. This metal is found in nature, principally in union with arsenic. By the exposure of the mineral, thus containing it, to heat, with access of air, the arsenic is oxidized and expelled, and the cobalt is reduced to the state of an impure oxide, called *zaffre*. By fusion with the alkali and sand, *zaffre* yields a beautiful blue glass, which, when pulverized, forms the blue vitreous powder called *smalt*.

1976. *Cobalt* may be obtained from its oxide, by intense ignition with charcoal, or by subjecting it, while ignited in a porcelain tube, to a current of hydrogen.

1977. *Cobalt* is brittle, of a grayish-white colour, and feeble lustre. Its specific gravity is 8.5 nearly. It requires a high temperature for its fusion.

## OF COLUMBIUM.

1978. A metal discovered by Hatchett, in 1801, in a mineral obtained from America, received the name of *columbium*. It was afterwards detected by Ekeberg in two Swedish minerals, called *tantallite* and *yttrotantalite*; and being supposed to be a new metal, was called *tantalum*. Wollaston afterwards demonstrated the identity of *tantalum* with *columbium*.

1979. This metal is found in the state of an acid, combined either with manganese and a little iron, or with yttria. Both combinations are very rare. It may be reduced by heating the fluocolumbate of potassium, or fluoride of *columbium* and potassium, with potassium.

1980. *Columbium* is a brittle metal, of an iron-gray colour, having the metallic lustre. It is infusible by the most intense heat of the forge fire.

## OF MANGANESE.

1981. *Manganese* exists in nature principally in the state of a black bioxide; rarely in that of phosphate, sometimes in the state of sulphide. The utility of this oxide, as a source of oxygen gas, as an ingredient in glass, and as one of the agents for evolving chlorine, has been noticed. (663.) The metal is obtained by heating the oxide intensely with charcoal or potassium. It is gray, brittle, hard, and scarcely fusible by the highest heat of the forge, or air furnace. In the metallic state, it has not been applied to any useful purpose.

1982. *Manganese* is remarkable for the number of compounds which it forms with oxygen. Besides a protoxide, sesquioxide, and bioxide, it forms two acids, the manganic, and oxymanganic or permanganic acids. The salts of the latter detonate with combustibles.

1983. When the black oxide (bioxide) is fused with nitrate of potash, a compound results, of which the aqueous solution becomes blue, violet, and red, and finally colourless. Hence this compound has been called *chameleon mineral*. These colours appear to be produced by the conversion of the manganate of potash, into an oxymanganate.

## OF MOLYBDENUM.

1984. This metal is only found in the state of sulphide, resembling plumbago, or united with oxygen and lead in the state of molybdate of lead. From the sulphide it is obtained by ebullition with nitric acid, which acidifies both the sulphur and metal. The sulphuric acid being expelled by heat, the molybdic acid is decomposed by intense ignition with charcoal.

1985. As from the difficulty of fusing it, molybdenum has been only used in small grains, its properties are but little known. It is alleged to have a high degree of metallic lustre, and a white colour.

#### OF TITANIUM.

1986. *Titanium*, like many other metals, is only interesting as an item of knowledge which human skill and assiduity have accumulated, with respect to the materials of the globe which we inhabit. It is obtained by separating the oxide from the substances with which it is naturally mixed, and heating it intensely with charcoal.

1987. *Titanium* was first ascertained to exist in the state of oxide, by Gregor, in a mineral called *menachanite*. It was subsequently detected in the metallic state by Dr. Wollaston, in minute cubic crystals, in the slag left at the bottom of a smelting furnace.

1988. These crystals were conductors of electricity, of the specific gravity of 5.3, and hard enough to scratch rock crystal. In colour and lustre, they were like burnished copper. They resisted the action of nitric acid and aqua regia, but were oxidized by being heated with nitre.

#### OF TUNGSTEN.

1989. In 1781, Scheele, having analysed a stone known by the name *tungsten*, or heavy stone, concluded that it consisted of an acid united with lime. Bergmann suspected the radical of this acid to be metallic. Mr. D'Elhuyart verified his conjecture, by heating tungstic acid intensely with charcoal.

1990. *Tungsten* is grayish-white, brilliant, and extremely difficult to fuse. Its specific gravity is 17.6.

#### OF URANIUM.

1991. *Uranium* is a rare production in nature, and has scarcely been found in sufficient quantities for an adequate observation of its properties. It is stated to have the metallic lustre, a reddish-brown colour, to be crystalline in its structure, and scarcely susceptible of fusion by the heat of a charcoal fire.

#### OF CERIUM.

1992. *Cerium*, according to Vauquelin, who was unable to obtain it in pieces larger than the head of a common pin, is a white brittle metal. From some experiments made by Children and Thomson, it appears to be susceptible of volatilization.

#### OF VANADIUM.

1993. *Vanadium* was discovered, in 1801, by Del Rio, in a lead ore from Zimapan, in Mexico; but Collet Descotils, to whom the mineral was first having made some new experiments upon it, pronounced it to be an oxide of chromium. Del Rio himself having acquiesced in this opinion, it was generally adopted until 1830, when Sefstrom discovered this metal in a variety of Swedish iron, and in the scoria of the forge at which the iron had been wrought.

1994. *Vanadium* resembles molybdenum in appearance; and in its properties lies between that metal and chromium.

*Experimental Illustrations.*

1995. Exhibition of various specimens of the metals mentioned in the preceding pages. Magnetic influence of nickel, demonstrated. Solutions of silver, mercury, and lead, precipitated by chromate of potash. Sesquioxide of chromium, evolved by heating the chromate of mercury. Exhibition of the fluoride of chromium. Effects of cobalt, also of manganese, upon vitrified borax.

## SALTS.

1996. In my preliminary exposition of the grounds of the classification and nomenclature adopted in this work, I alleged the word salt to be insusceptible of any definition consistent with the use made of it by Berzelius as a basis of nomenclature. As the reader, who has studied this work so far, as to have reached this page in due course, should have acquired a knowledge of the facts upon which the above cited allegation was founded, I will here quote the language in which those facts were stated, and my inferences from them justified.

1997. The most striking feature in the nomenclature of Berzelius, is the formation of two classes of bodies; one class called "*halogene*," or salt producing, because they are conceived to produce salts directly; the other called "*amphigene*," or both producing, being productive both of acids and bases, and of course indirectly of salts. To render this division eligible, it appears to me that the terms acid, base, and salt, should, in the first place, be strictly defined. Unfortunately there are no terms in use, more broad, vague, and unsettled in their meaning. Agreeably to the common acceptation, chloride of sodium is pre-eminently entitled to be called a salt; since in common parlance, when no distinguishing term is annexed, salt is the name of that chloride. This is quite reasonable, as it is well known that the genus was named after this compound. Other substances, having in their obvious qualities some analogy with chloride of sodium, were, at an early period, readily admitted to be species of the same genus; as, for instance, Glauber's salt, Epsom salt, sal ammoniac. Yet founding their pretensions upon similitude in obvious qualities, few of the substances called salts, in the broader sense of the name, could have been admitted into the class. *Insoluble* chlorides have evidently, on the score of properties, as little claim to be considered as salts, as *insoluble* oxides. *Luna cornea*, *plumbum corneum*, butter of antimony, and the fuming liquor of Libavia, are the appellations given respectively to chlorides of silver, lead, antimony, and tin, which are quite as deficient of the saline character as the corresponding compounds of the same metal with oxygen. Fluoride of calcium (fluor spar) is as unlike a salt as lime, the oxide of the same metal. No saline quality can be perceived in the soluble "haloid salts," so called by Berzelius, while free from water; and when a compound of this kind is

stened, even by con the e, it may be considered as a salt  
 red of an hydracid and an oxyb , produced by a union of the hydro-  
 of the water with the halogene , and of the oxygen with the  
 cal. It is admitted by Berzelius, s, page 330, that it cannot be  
 onstrated that the elements of t w ; and those of an haloid salt,  
 olved in that liquid, do not exist n t of an hydracid and an oxy-  
 , forming a salt by their obvious n.

998. On the other hand, if, inst of qualities, we resort to composi-  
 as the criterion of a salt; if, as in some of the most respectable che-  
 d treatises, we assume that the word salt is to be employed only to de-  
 ate compounds consisting of a base united with an acid, we exclude  
 the class chloride of sodium, and all other "haloid salts," and thus  
 set the basis of the distinction between "*halogens*" and "*amphigene*"  
 ents.

999. Moreover, while thus excluding from the class of salts, substances  
 ch the mass of mankind will still consider as belonging to it, we assem-  
 under one name combinations opposite in their properties, and destitute  
 he qualities usually deemed indispensable to the class. Thus under the  
 nition that every compound of an acid and a base, is a salt, we must  
 ch this name to marble, gypsum, felspar, glass, and porcelain, in com-  
 with Epsom salt, Glauber's salt, vitriolated tartar, pearlash, &c. But  
 itting that these objections are not sufficient to demonstrate the absurdity  
 defining a salt, as a compound of an acid and a base, of what use could  
 a definition be, when, as I have premised, it is quite uncertain what is  
 acid, or what is a base. To the word acid, different meanings have  
 a attached at different periods. The original characteristic sourness is  
 longer deemed essential! Nor is the effect upon vegetable colours treated  
 an indispensable characteristic. And as respects obvious properties, can  
 re be a greater discordancy, than that which exists between sulphuric  
 d, and rock crystal; between vinegar, and tannin; or between the vola-  
 , odoriferous, liquid poison, which we call prussic acid, and the inodo-  
 , inert, concrete material for candles, called margaric acid?

1000. While an acid is defined to be a compound capable of forming a  
 with a base, a base is defined to be a compound that will form a salt  
 h an acid. Yet a salt is to be recognised as such, by being a compound  
 the acid and base, to which, as I have stated, it is made an essential  
 an of recognition.

1001. An attempt to reconcile the definitions of acidity given by Berze-  
 , with the sense in which he uses the word acid, will, in my apprehen-  
 , increase the perplexity.

1002. It is alleged in his *Traité*, page 1, Vol. II., "*that the name of  
 d is given to silica, and other feeble acids, because they are susceptible  
 combining with the oxides of the electropositive metals, that is to say,  
 h salifiable bases, and thus to produce salts, which is precisely the  
 nicipal character of acids.*" Again, Vol. I., page 308, speaking of the  
 logene elements, he declares that "their combinations with hydrogen, are  
 t only acids, but belong to a series the most puissant that we can employ  
 chemistry; and in this respect they rank as equals with the strongest of  
 acids, into which oxygen enters as a constituent principle." And again,  
 d. II., page 162, when treating of hydracids formed with the halogene  
 se, he alleges "*The former are very powerful acids, truly acids, and  
 feebly like the oxacids; but they do not combine with salifiable bases;  
 the contrary, they decompose them, and produce haloid salts.*"

2003. In this paragraph, the acids in question are represented as pre-eminently endowed with the attributes of acidity, while at the same time they are alleged to be destitute of his "*principal character of acids*," the property of combining with salifiable bases.

2004. In page 41, (same volume,) treating of the acid consisting of two volumes of oxygen and one of nitrogen, considered by chemists generally as a distinct acid, Berzelius uses the following language. "If I have not coincided in their view, it is because, judging by what we know at present, the acid in question cannot combine with any base, either directly or indirectly; that consequently it does not give salts, and that salifiable bases decompose it always into nitrous acid, and nitric oxide gas. It is not then a distinct acid, and as such, ought not to be admitted in the nomenclature." Viewing these passages with all that deference which I feel for the productions of the author, I am unable to understand upon what principle the exclusion of nitrous acid from the class of acids, can be rendered consistent with the retention, in that class, of the compounds formed by hydrogen with "*halogene*" elements.

2005. It is certainly to be regretted that there should be so much difficulty in giving a precise meaning to a word used so extensively as that which led to the language above quoted. The best definition which I can devise, in this case, is that a salt is a compound, resulting from the union of at least two acid, acrid, or corrosive ingredients; forming, agreeably to the language of the older chemists, a *tertium quid*, or in plain English, a *third something*, differing materially from its constituents. It should, as I conceive, be crystallizable, and soluble either in water or alcohol. I do not think that a satisfactory line of demarcation can be drawn between salts, acids, and bases. Some compounds which lean so much towards *salinity*\* in their characteristics, as to have been classed with salts, have latterly been found to play the part of acids or bases, as instanced by the binary halogen salts. I would consider them as salts when acting as such, and as acids or bases when acting as acids or bases. Berzelius has suggested this kind of contingent definition in the instance of water; which he represents as acting as a base with some acids, and as an acid with some bases. Thus it seems possible for the same body to act either as an acid, a salt, or a base, accordingly as it may be associated.

### *Of the Principal Groups of Salts.*

2006. As respects composition, I conceive that there are at least three groups of salts.

2007. 1st. Binary saline compounds of a halogen element and a metal.

2008. 2d. Saline compounds of acids and bases, *tertium quids* agreeably to the definition of acidity and basicity. (631.)

2009. 3d. Saline compounds containing either an organic acid or an organic base; or consisting of such an acid, united with such a base.

\* I am unable to refer to any authority for the use of this word, but conceive myself justified in employing it, as, by analogy, it cannot be misunderstood by the reader.

1. As far as consistent with the due allotment of I have given an account of the first group in treat- the metals. But the class thus constituted are e of combining with each other, and with the electro- ve or acid compounds, formed by the union of their a ingredients with non-metallic radicals. In this ompounds are produced, which Berzelius designates ble haloid salts. I, however, consider them as much l to be treated as saline compounds of acids and as the double sulphides, selenides, or tellurides, are so treated by that distinguished chemist. (627.) l. I shall designate the salts comprised in the 1st groups abovementioned by their basacigen ingredi- 633.) Hence the nine following classes; *oxysalts*, *alts*, *selenisalts*, *tellurisalts*, *chlorosalts*, *bromosalts*, *ts*, *fluosalts*, and *cyanosalts*. Obviously, of these the ar are formed by the *amphigen bodies*, and the rest *halogen bodies* of Berzelius.

## SECTION I.

### OF OXYSALTS.

2. In describing the oxysalts, I shall be constrained fine my remarks to some of the more important teristics of each of the sets of salts formed by the it inorganic oxacids with the more energetic bases. of those formed by acids of minor importance will tted altogether.

#### *Of Chlorates and Hypochlorites.*

1. As agreeably to the premised arrangement, the a, first made the objects of attention in this work, ose formed by the union of chlorine with oxygen; ws that the saline combinations formed by those with bases, should be the first to be treated of oxysalts.

1. We have four acids consisting of the two ele- abovementioned, and, consequently, should have pecies of salts, hypochlorites, chlorites, chlorates, archlorates, or oxychlorates. It seems, however, al whether *chlorous* acid can be presented to a base, t being resolved into a chlorate and chlorine. In spect, it seems to rest on the same footing as ni-

trous acid. (984, 2004.) Of course there are no chlorites.

2015. The chlorates and hypochlorates are the products of one process, in which an oxybase is made to react with chlorine. In the process alluded to, a fixed alkali, or any of the three more powerful alkaline earths, whether in solution, in a state of suspension, or in the pulverulent state of a hydrate, being sufficiently exposed to chlorine, is found to acquire the bleaching and disinfecting properties with which that gas is so remarkably endowed.

2016. In the case in which a solution of potassa is saturated with the gas, besides the acquisition of bleaching power, by the mother water, crystals result of chlorate of potash, which from their inferior solubility precipitate.

2017. This process was rather an empirical improvement, when first employed; because, agreeably to the science of the day, nothing could have been less likely to succeed. At that time, chlorine was considered as an oxacid of an unknown radical. (886.) But if the bleaching and disinfecting properties of chlorine were due to acidity, nothing could be less consistent with the retention of those properties, than saturation with powerful base. Subsequently, when the elementary character of chlorine became known, the ascertained retention of its bleaching and disinfecting power, after combination with an oxybase, appeared much more consistent with the supposed nature of the ingredients.

2018. It was conceived, that chlorine feebly attracted to an oxybase, was liberated by its affinity for colouring matter, or feculent emanations, or by the affinity of another principle for the oxybase. Accordingly, until within the last ten years, the impression generally prevailed, that the liquids, powders, or salts employed in bleaching, were compounds of an oxybase with chlorine. Hence, the terms chloride of lime, or chloride of potassa, or of soda, which are still in use, especially among manufacturing chemists.

2019. It was in the treatise of Berzelius, that I first met with the explanation which I gave in the last edition of this text book, of the process under consideration, and which I now subjoin.

2020. When into a solution of potash, (oxide of potassium,) chlorine is introduced, one portion of it combines



with the potassium, separating from each atom the atom of oxygen by which it was oxidized. The oxygen thus liberated from several atoms of the metal, coming into contact with another portion of chlorine, forms with it chlorous acid. Each atom of the acid, thus formed, unites with an atom of potash, producing a chlorite. By continuing the operation until all the potash which remains free is decomposed, that which has meanwhile united with the acid is attacked by the chlorine, and the oxygen, liberated in consequence from each atom of the chlorite, converts another portion of this salt into a chlorate. This salt being inferior in solubility to the chloride, precipitates in crystals, which being subjected to boiling water, are purified by the recrystallization which cooling induces.

2021. This explanation seems to require modification, only so far as to introduce the hypochlorous in lieu of the chlorous acid, (688,) agreeably to the new view of the subject presented in treating of the compounds of chlorine with oxygen. Reference is there made to the investigations of Balard, by which it has been shown that the gaseous product supposed to be the protoxide of chlorine, called *euchlorine* by Davy, is really a mixture of chlorous acid with chlorine; and also that the real protoxide of chlorine, is the acid which is formed during the process for making chlorate of potash, or bleaching powders, and which is now designated as hypochlorous acid.

2022. The impure hypochlorite of lime, called *bleaching salt*, is obtained by exposing hydrate of lime to chlorine. Analogous salts of potash and soda are found in the mother waters of the chlorates of those alkalies, and may likewise be obtained, by double decomposition, from the hypochlorite of lime, and carbonate of potash or soda. When obtained by these methods, hypochlorites are mingled with the chlorides of the metals peculiar to their respective bases.

2023. *Properties.*—The hypochlorites are extremely susceptible of decomposition. This, however, takes place in a manner which varies with the circumstances in which they are placed. Bleaching or disinfection is effected by them when quite pure, by imparting oxygen; being resolved into this element and a chloride. Chlorine produces similar effects, by causing water to impart oxygen. No doubt the result is the consequence of complex affinity,

the hydrogen being attracted by the chlorine, the oxygen by some oxidizable substance.

2024. When carbonic acid has access to an hypochlorite, it combines with the base of the salt, displacing the acid; and if a chloride be present, its radical is oxidized by the oxygen of the acid thus displaced; while its chlorine is liberated, as well as that of the chlorous acid. Of course an evolution of chlorine must ensue from the employment, in like case, of any acid, which, in its affinities, is not less energetic than carbonic acid. If, however, a pure hypochlorite, formed by the action of hypochlorous acid on a base, be subjected to the action of a more powerful acid, the hypochlorous acid may be liberated without being decomposed.

2025. When an aqueous solution of a hypochlorite is boiled in pure water, one portion of the chlorite is converted into a chloride; while the oxygen, which is liberated from it during this transformation, converts another portion into a chlorate.

2026. According to Thomson, when chloride of ammonium is introduced into a retort containing the hypochlorite of lime of commerce, made into a paste with water, gaseous nitrogen is evolved with a reaction so violent, that, in order to delay the extrication until his arrangements for collecting the product were completed, he found it expedient to wrap the hypochlorite in blotting paper.

#### *Experimental Illustrations.*

2027. Production of hypochlorite of lime. Its effects upon colouring matter. Evolution of nitrogen from chloride of ammonium, by hypochlorite of lime.

#### *Properties of the Chlorate.*

2028. The chlorates resemble the nitrates in deflagrating with combustibles; but the residuum which they leave is always a chloride; and the deflagration is more powerful and more easily effected. If chlorate of potash be triturated in contact with sulphur or phosphorus, an explosion ensues. Salts of this class give up their oxygen, and are converted into chlorides, simply by being heated. They are almost all soluble in water. The chlorate of the protoxide of mercury is said to be but sparingly soluble.

2029. The properties of the chlorates are most conveniently illustrated by the chlorate of potash, which is an efficient material in several varieties of the matches which are ignited either by contact with sulphuric acid, by friction, or crushing.

2030. Alcohol, or any of the essential oils, oil of turpentine for instance, may be ignited by means of chlorate of potash and sulphuric acid.

### *Experimental Illustrations.*

2031. Ignition of phosphorus with chlorate of potash by percussion. Explosion of sulphur mixed with the chlorate, by trituration. Composition for friction matches consisting of chlorate of potash, sulphur, and phosphorus, mingled with gum, exhibited and ignited. About as much chlorate of potash as may be piled upon a half cent, being deposited in a heap amid the inflammable liquid, the addition of concentrated sulphuric acid upon the heap, causes the liquid to be inflamed.



*Combustion of Phosphorus under Water, by means of Chlorate of Potash and Sulphuric Acid.*

2032. Let there be two tubes, one within the other, as here represented; the larger one, closed at the lower end, and containing water; the other open at both ends, the upper orifice funnel-shaped, and the bore about one-twelfth of an inch in diameter. Allow some very small pieces of phosphorus, and a few crystals of chlorate of potash, to fall down to the bottom of the large tube. Then, into the smaller tube, pour some sulphuric acid; so that, without being much diluted, it may descend upon the chlorate and phosphorus. A vivid ignition ensues, in despite of the surrounding water.

2033. The sulphuric acid, uniting with the potash of the chlorate, liberates chlorine and oxygen, which, coming into contact with the phosphorus, cause its combustion.

*Of Perchlorates or Oxychlorates.*

2034. One of the processes for procuring oxychlorate of potash, has been mentioned in the text, while treating of oxychloric acid, (712,) and another is mentioned in a note. Oxychlorates of other bases, are obtained either by double decomposition; or by the direct union of the acid, made as already suggested. (713.)

2035. The oxychlorates, in general properties, resemble the chlorates. They appear, however, to be less susceptible of decomposition; since the oxychlorate of potash is not decomposed by any of the acids at ordinary temperatures, and does not react as violently with sulphur as the chlorate of potash.

2036. Nearly all of the oxychlorates would appear to be deliquescent, and soluble in alcohol, excepting those of potash, lead, protoxide of mercury, and ammonia. At the temperature of  $59^{\circ}$ , oxychlorate of potash requires for its solution sixty-five times its weight of water.

## OF NITRATES.

2037. This class of salts is distinguished by deflagrating with charcoal and other combustibles. When the combustible is susceptible of acidification, the resulting acid unites always with the base. Thus in the case of charcoal, a carbonate is left; in the case of silicon, a silicate; in the case of sulphur, a sulphate; in the case of arsenic, an arseniate. They differ from the oxysalts containing an acid with a halogen radical (the chlorates for instance,) in leaving an oxide after deflagration, instead of a haloid salt. Thus the nitrate of potash leaves the oxide of potassium; while the chlorate leaves a chloride of potassium.

2038. If subjected to concentrated sulphuric acid, the nitrates, when dry, emit fumes of nitric acid. When added to liquid chlorohydric acid, by dehydrogenating the chlorine, they enable it to act on gold leaf, as it does when presented to this metal in aqua regia.

2039. *The neutral nitrates are all soluble, and many of them deliquescent.*

*Experimental Illustrations.*

2040. Deflagration of a nitrate upon ignited charcoal, and of charcoal and other substances upon fused nitrate of

otash, soda, copper, or strontia. A nitrate added to liquid chlorohydric acid containing gold leaf, causes the solution of the metal. Decomposition of a nitrate by heat.

#### OF NITRITES AND HYPONITRITES.

2041. It would appear that the compound, which, consistently with the practice of the British and French chemists, has been designated as nitrous acid, is decomposed when presented to bases, forming a nitrate and hyponitrite. It is probable, therefore, that there are no salts which properly deserve the name of nitrites, in the sense in which this appellation has been used by the chemists abovementioned. It has already been stated that Berzelius does not admit the existence of any acid intermediate, as respects the quantity of oxygen contained, between nitric and hyponitrous acid, and, therefore, calls the acid to which the last mentioned name has been applied, nitrous acid, and of course designates its compounds as nitrites. (984.) The hyponitrites of the English and French chemists, or nitrites of Berzelius, resemble the nitrates in most of their properties; but may be recognised by the red vapours which they evolve on the addition of any of the stronger acids. (981, &c.)

#### OF SULPHATES.

2042. Their solutions all yield precipitates with solutions of baryta. Heated in contact with charcoal or hydrogen, they are converted into sulphurets, which, if moistened, smell like rotten eggs. They are almost all insoluble in alcohol. The sulphates of baryta, tin, antimony, bismuth, and lead, are *quite* insoluble in water. Those of strontia, lime, yttria, mercury, silver, and the sesquioxide of cerium, are *nearly* insoluble; while all other sulphates are soluble.

#### *Experimental Illustrations.*

2043. Precipitation of sulphates by solutions of baryta. Conversion of a sulphate into a sulphuret before the blow-pipe, demonstrated by the subsequent effect upon a metallic solution.

## OF HYPOSULPHATES, SULPHITES, AND HYPOSULPHITES.

2044. The hyposulphate of baryta, is obtained by adding sulphide of barium to a solution of hyposulphate of manganese. (764.) The hyposulphates of lime and strontia are procured in the same manner, and the hyposulphates of the other bases, either by double decomposition, or by adding the acid directly to the base.

2045. The neutral *hyposulphates* are probably all soluble. This property, together with their conversion into sulphates by heat, and the odour of sulphurous acid which they emit on the addition of concentrated sulphuric acid, is sufficient to enable us to recognise them.

2046. The insoluble *sulphites* are obtained by double decomposition; those which are soluble, by the direct action of the acid on the base.

2047. The sulphites are generally insoluble, and may be recognised by the odour of sulphurous acid which they emit on the addition of dilute sulphuric acid; while they do not, like the hyposulphites, simultaneously deposit sulphur: also by their not yielding, like the hyposulphates, a neutral sulphate by heat.

2048. The *hyposulphites* are procured by treating metallic zinc, iron, or manganese, with liquid sulphurous acid. Each atom of this acid abandons one atom of oxygen to the metal, being consequently converted into hyposulphurous acid, which, with the resulting oxide, forms a hyposulphite.

2049. The hyposulphites may likewise be formed by boiling sulphites with flowers of sulphur, by which each atom of acid in any sulphite takes up an additional atom of sulphur, converting the sulphite into a hyposulphite.

2050. The hyposulphites may all be decomposed by heat, and, when acted on by sulphuric acid, deposit sulphur and liberate sulphurous acid.

## OF SELENIATES.

2051. The seleniates greatly resemble the sulphates in properties. They are in fact isomorphous with them, and crystallize with the same quantity of water of crystallization. The seleniates are, however, more susceptible of decomposition than the sulphates, and when thrown on burning coals deflagrate.

## OF PHOSPHITES.

2052. The phosphites are obtained either by presenting the acid directly to the base, or by double decomposition. When thrown on burning coals they produce a yellow flame, the colour of which increases in intensity with the quantity of acid contained in the salt.

## OF PHOSPHATES.

2053. The phosphates all give precipitates with solutions of baryta, lime, lead, and silver.

2054. The phosphates are not decomposable by heat alone. Those of the metals proper may be converted, by heat and charcoal, into phosphurets of the metals peculiar to their respective bases. In the case of the phosphates of the earths and alkalies, a portion of the phosphoric acid

deoxidized by the carbon, evolving phosphorus; while the remainder forms with the base a subphosphate.

2055. By heat the phosphates are converted into paraphosphates, identical in composition, though different in properties.

2056. According to Thenard, phosphoric acid combines with bases in five different proportions, forming *biphosphates*, *sesquiphosphates*, *neutral phosphates*, *sesquibasic phosphates*, and *bibasic phosphates*, in which the equivalents of acid to those of the base are respectively as 2 to 1,  $1\frac{1}{2}$  to 1, to 1, 1 to  $1\frac{1}{2}$ , and 1 to 2.

#### OF CARBONATES.

2057. This class of salts is distinguished by being susceptible of decomposition, with effervescence, by any of the acids, excepting a few that are remarkably feeble, as, for instance, the cyanhydric and meconic acids.

2058. All the alkaline carbonates are decomposable by heat, excepting those of potassa, soda, baryta, strontia, and probably lithia.

2059. Each of the alkalies, potash, soda, and ammonia, forms with carbonic acid, a carbonate, consisting of an equivalent proportion of each ingredient; a sesquicarbonate, in which there are one equivalent and a half of acid to one of alkali; and a bicarbonate, in which there are two equivalents of the acid to one of alkali. When saturated with the acid, they are more susceptible of crystallization, and less nauseous to the taste.

2060. The evolution of the acid from the carbonates of lime and ammonia has been already exhibited.

#### OF BORATES.

2061. The baborate of soda is found in nature in certain lakes, and is known in commerce as borax. In the examination of minerals by the blowpipe, it is very useful.

2062. The other soluble borates, which are those of potash, soda, lithia, and ammonia, are obtained by uniting the acid directly with the base. The insoluble borates, which are quite or nearly insoluble, are procured by double decomposition with the borate of soda. Borates are undecomposable by heat, when their bases are undecomposable by that agent. Other borates, when intensely heated, are resolved into oxygen, a metallic radical, and boric acid.

#### OF SILICATES.

2063. The silicates are procured either by double decomposition, or by uniting silicic acid strongly with the base. They are not decomposable by

heat alone; although, when heated with charcoal, some of the silicates are converted into silicurets. All the silicates, excepting those of potash, soda, and lithia, are insoluble.

### OF CYANATES AND FULMINATES.

2064. The soluble cyanates are decomposable by water, and, if insoluble, by acids, into carbonic acid and ammonia. The fulminates are chiefly remarkable for the violent explosions which they produce by heat or percussion. The fulminate of mercury is employed as priming in percussion gun locks. It may be obtained by the following process: Dissolve 100 grains of mercury with heat in a measured ounce and a half of nitric acid of moderate strength; when cold, mix the solution with a measured ounce and a half of alcohol, and apply heat till effervescence takes place. When red fumes appear, check the action with water. The powder which precipitates, well washed with water, and afterwards dried at a gentle heat, will be the fulminate of mercury.

### OF DOUBLE OXYSALTS.

2065. There are many cases in which two salts, formed by different bases but of the same acid, enter into combination. A compound thus constituted, formerly received the appellation of a triple salt, but is now designated as a double salt.

2066. Tartar emetic is a double tartrate, consisting of tartrate of potash combined with tartrate of antimony. (1919.)

2067. Rochelle salt is a compound of tartrate of potash with the tartrate of soda. An analogous compound is formed by the union of tartrate of potash with tartrate of iron, called *ferri et potassæ tartras*, or tartrate of potash and iron, in the United States' Dispensatory; to which I refer students for much valuable information which my limits will not allow me to add.

2068. The saline compound, well known under the name of alum, is composed of one atom of trisulphate of alumina, and one of sulphate of potash, besides twenty-four atoms of water of crystallization.

2069. Other double sulphates have been formed analogous to alum, substituting soda or ammonia for potash, or iron, manganese, or chromium for alumina.

2070. Double silicates and carbonates exist in nature. Dolomite is a species of marble, consisting of the carbonates of lime and magnesia in equivalent proportions. Felspar consists of a silicate of alumina and a silicate of potash. Many native crystals, well known to mineralogists, are double silicates.

2071. Glass, in general, is a combination of one or more silicates. Fine glass, according to Turner, is a double sexsilicate of lead and potash.

2072. It ought not to be supposed that double salts are always produced by the combination of single salts previously existing separately. In the case of tartar emetic, the bitartrate of potash, containing two equivalents of acid to one of base, is converted into the double tartrate of potash and antimony, by saturating with one equivalent of the sesquioxide of this metal, one equivalent of the acid in the bitartrate. Thus a tartrate of antimony is produced in combination with a tartrate of potash, and a double salt is of course formed.

2073. It appears possible for two double salts to combine, as when bitar-



soda (borax) is added to bitartrate of potash, in order to produce soluble cream of tartar" of pharmacy. According to Berzelius, this und may be considered as consisting of a double tartrate of potash da (sal Rochelle), combined with a double tartrate of potash, and cid acting as a base. See United States' Dispensatory.

## SECTION II.

### OF SULPHOSALTS.

1. Berzelius alleges that the metallic sulphides, which are capable of combining with each other to form sulphosalts, contain for each atom of sulphur, the same number of atoms of sulphur, as the salifiable oxybases and acids of the same radicals contain of oxygen. In consequence of analogy in composition, if sulphydric acid gas be transmitted through a concentrated solution of an oxysalt, in which the acid and base have a metallic radical, the hydrogen of the sulphydric acid takes all the place from both radicals. Meanwhile, an equivalent number of atoms of sulphur, consequently liberated, take the place of the oxygen, forming a salt, consisting of a sulphacid and a sulphobase, analogous, in the proportions of atoms of each ingredient, to the oxysalt, from the decomposition of which it originates.

5. In order, however, to effect the combination of the electro-positive metallic sulphides which act as bases, with the sulphides of non-metallic elements which act as sulphacids, a different method must be adopted. In the case of sulphydric acid gas, which does not combine, except with the oxides of the metals of the alkaline earths and alkalies, it is either introduced into contact with a carbonate of the base heated to redness, or made to enter into a solution of the hydrate. Whichever method be adopted, no access of atmospheric oxygen should be allowed. In either case, a portion of the sulphydric acid is decomposed, its hydrogen combining with the oxygen of the base, and its sulphur with the metal; while the other portion of the acid unites with the sulphide thus formed, producing a sulphhydrate.

6. It has been stated, (1248,) that combinations of sulphocarbonic acids may be formed with most of the electro-positive sulphides, either by direct union, or by double decomposition. There are other methods of preparing these sulphosalts, of which I cannot treat, consistently with the limits prescribed for this work.

## SECTION III.

### OF SELENISALTS AND TELLURISALTS.

7. As has been already stated, both selenium and tellurium are capable of combining with different radicals, forming selenides and tellurides.

These, in many cases, like the corresponding compounds formed by arsenic, unite together to form selenisalts and tellurisalts. The resulting combinations, however, have been but little studied.

## SECTION IV.

OF CHLOROSALTS, BROMOSALTS, IODOSALTS, AND  
FLUOSALTS OF THE SECOND GROUP.

2078. The *chlorosalts* are generally obtained by mingling chloracids with chlorobases (631), either in the wet or dry way. In the latter case, heat must be employed in order to facilitate their union.

2079. The *bromosalts* and *iodosalts* may in general be obtained in the same manner, by mingling bromacids with bromobases, or iodacids with iodobases.

2080. I have mentioned, in treating of the chlorides of the metals, several instances in which combinations are formed by them with chlorohydric acid. Such compounds, however, are rare, and, when they do occur, appear not to possess stability.

2081. I have stated (1396,) my opinion that the compounds, designated by Berzelius as fluohydroboric acid and fluohydrosilicic acid, should be considered as tertium quids, in which the fluoride of hydrogen performs the part of a base, while the fluorides of boron and silicon act as acids. Hence fluohydroboric acid is a fluoborate of hydrogen, and fluohydrosilicic acid, a fluosilicate of hydrogen.

2082. With the fluorides of columbium and titanium, the fluoride of hydrogen forms compounds analogous to those abovementioned, and which I would designate as fluocolumbate, and fluotitanate of hydrogen.

2083. When any fluosalt like those abovementioned, in which hydrogen exists as a radical, is brought into contact with an oxybase, of which the radical is capable of forming a fluobase, the hydrogen unites with the oxygen of the oxybase, while the radical of this base unites with the fluorine. The fluacid of the fluosalt, consequently liberated, combines with the resulting fluobase.

2084. The other fluosalts are formed by the direct reaction of the fluacids and fluobases which compose them, either in the wet or dry way. By adding fluohydric acid to the fluorides of potassium and sodium, fluohydrates of those fluobases may be formed. (1398.)

## SECTION V.

## OF CYANOSALTS.

2085. The cyanosalts are in general obtained either by the direct union of a cyanacid with a cyanobase, or by decomposition. It is by the latter method that the cyanoferrite of potassium is formed, the sulphate of the protoxide of iron being presented to the cyanide of potassium. In this case the sulphuric acid, and the oxygen of the protoxide of iron, are transferred to one portion of the potassium. The cyanogen, consequently liberated, forms with the iron, cyanoferrous acid, which unites with the undecomposed portion of the cyanide of potassium. (1299, &c.)





# COMPENDIUM

OF

THE COURSE OF CHEMICAL INSTRUCTION

IN

THE MEDICAL DEPARTMENT

OF

THE UNIVERSITY OF PENNSYLVANIA.

BY

ROBERT HARE, M.D.

PROFESSOR OF CHEMISTRY.



## PART II.

COMPRISING THE

CHEMISTRY OF ORGANIC SUBSTANCES; BEING A COMPENDIOUS SELECTION FROM THE PREVIOUS EDITION: THE "TREATISE OF ORGANIC CHEMISTRY," BY LIEBIG: GREGORY'S TURNER: KANE'S "ELEMENTS," AND THOSE OF GRAHAM: INTERSPERSED WITH SOME ORIGINAL MATTER.



Also, a Letter on the Berzelian Nomenclature, with the Reply of Berzelius; with some Subsequent Remarks and Suggestions by the Author.

And an Effort to Refute the Arguments advanced in favour of the Existence of Compound Radicals, like Cyanogen, in the Amphide Salts; with a subjoined Statement of those Arguments as advanced in Kane's Elements.



PHILADELPHIA:

SOLD BY J. G. AUNER, No. 333 MARKET STREET,

AND

CAREY & HART, CORNER OF FOURTH AND CHESNUT STREET.

John C. Clark, Printer, 60 Dock Street.

1843.

•

•

•

•

# OF ORGANIC CHEMISTRY,

OR

## THE CHEMISTRY OF ORGANIC SUBSTANCES.

---

### CONTENTS.

Organic substances defined—Of organic hydrates, erroneously considered as such—  
Influence of heat upon vegetables, with and without access of air—Ultimate  
analysis of organic substances—Of the mode in which their ultimate elements  
are associated—Of compound radicals—Of substitution, Page 373 to 379

#### OF COMPOUND RADICALS.

Of amide—Carbonic oxide—Benzole, benzoile, or benzyl—Cinnamyl—Salicyl—  
Ethyl—Acetyl—Kacodyl—Mesityl, or minitylene—Methyl—Formyl—Amyl—  
Glyceryl—Cetyl, . . . . . Page 380 to 398

#### OF NUTRITIOUS VEGETABLE SUBSTANCES DEVOID OF NITROGEN.

Of Gum—Sugars—Grape sugar—Sugar of milk—Mushroom sugar—Fermentable  
matter of diabetes—Liquorice sugar—Manna sugar, . . . . . Page 400 to 406  
Of fecula, or starch—Of diastase, and of the conversion of fecula into dextrine and  
grape sugar—Lignin, . . . . . Page 406 to 409

#### OF VEGETO-ANIMAL SUBSTANCES.

Of gluten—Vegetable albumen—Gluten and albumen of wheat—Legumen, or ve-  
getable caseine, . . . . . Page 411 to 413  
Composition of vegetable fibrin, vegetable albumen, vegetable caseine, and vegeta-  
ble gluten—Composition of animal caseine, . . . . . Page 418 to 419

#### OF VEGETABLE COLOURING MATTER.

Of vegetable colouring matter, or dyes, and of dyeing—Of the colouring matter of  
leaves and flowers, . . . . . Page 419 to 420

#### OF OILS.

##### OF FIXED OILS.

Of stearine—Margarine—Olein—Saponification—Properties of the fixed oils,  
Page 424 to 426

##### OF VOLATILE OILS.

Of the resemblance and dissimilarities of the fixed and volatile oils—Volatile oils in  
particular—Volatile oils containing sulphur as an ultimate element—Volatile  
oil of mustard—Volatile oils containing oxygen—Volatile oils devoid of oxygen  
Of oil of turpentine—Camphor—Artificial camphor—Camphene, or camphelene,  
and terobene—Kreosote—Essential oils which are hydrurets—Hydruret of ben-  
zole, or oil of bitter almonds—Amiduret of benzole, or benzamide,  
Page 429 to 442

## OF SUBSTANCES MORE OR LESS RESINOUS.

Of resins—Wax—Caoutchouc, or gum elastic, and caoutchoucine—Balsams—Gum resins—Opium—Bitumen, petroleum, naphtha, amber, and mineral coal, . . . . . Page 442 to 458

## OF ACIDS.

Of acids relatively to the proportions of base required for their saturation—Formula for monobasic salts—Of acetic acid—Pyroligneous acid—Acetates—Acetate of ammonia, or spirit of mindererus—Lactic acid—Citric and malic acid—Tartaric acid, and paratartaric, or racemic acid—Liquid and solid pyrotartaric acid—Guaiacine, or guaiacinic acid—Tannic acid—Artificial tannin—Gallic acid—Meconic acid—A method of detecting the presence of opium—Acids formed from sugar—Formic acid—Valerianic acid—Caffeic acid and caffeic tannic acid—Acids modified by an union with organic matter—Acids modified by union with an oxidized compound radical—Sulphovinic acid, or the sulphate of ether, and water—Benzoic acid—Benzoic acid—Properties of benzoic acid—Hippuric acid—The hippurates—Formobenzulic acid, . . . . . Page 453 to 468

Of salicylic or salicylic acid, also called the hydruret of salicyl, but more properly considered as salicylic acid, and other compounds of salicyl—Of the acids from the oil of gaultheria, . . . . . Page 479 to 488

Salicylic acid with bases—Salicylate of ammonia—Salicylimide—Salicylate of potash; neutral—Salicylates of soda, lime, baryta, and magnesia—Basic salicylate of lead—Salicylate of silver—Melanic acid—Salicylic acid—Chlorosalicylic acid—Chlorosalicylimide—Bromosalicylic acid—Iodosalicylic acid—Nitrosalicylic acid, . . . . . Page 489 to 498

## OF URIL AND URIC ACID.

Of uric acid—Allantoin—Alloxan—Alloxanic acid—Mesoxalic acid—Mycomelic acid—Parabanic acid—Oxaluric acid—Thionuric acid—Uramile—Uramic acid—Alloxantin—Products of the decomposition of alloxantin—Murexide—Murexan—On the influence of benzoic acid in lessening the generation of uric acid in human urine, . . . . . Page 494 to 498

## OF ORGANIC ALKALIES OR BASES.

Table of the organic alkalies—Organic alkalies of doubtful existence—Of the state in which the organic alkalies exist in the products of vegetation, and the means of extricating them, generally described, . . . . . Page 493 to 496

Of morphia—Paramorphia—Codeia—Narcotina—Narcea—Quinia—On the reaction of chlorine with quinia and its salts—Of cinchona—Aricina—Strychnia—Ericia—Delphia—Veratria—Sabadilla—Jervina—Colchicina—Emetia—Solania—Caffein—Chelerythrina—Chelidonia—Atropia—Aconitia—Belladonia—Datura—Conina—Nicotina—Lobelina—Picrotoxine—Antiarine—Bases from the oil of mustard—Thiosinaminina—Sinaminina—Sinapolina—Cinchovine—Cissampelina—Hederina, surinamina, and jamaicina, . . . . . Page 496 to 513

Of certain general characteristics of the vegetable alkalies, distinguishing them from inorganic bases, and of those which distinguish them into several different sets. Constitution of the organic alkalies, . . . . . Page 513 to 520

## OF IMPORTANT NEUTRAL ORGANIC PRINCIPLES.

Of salicin, a neutral principle, and of some compounds derived from it, or to the production of which it contributes—Saliretine—Chlorosalicine—Rutiline—Phloridzine—Phloridzeine—Asparagine, asparamide, altheine, agedole—Taraxacine, . . . . . Page 521 to 534

*Of certain Vegetable Principles devoid of Nitrogen.*

Of gentianine—Santonine—Picrolichenine—Cetrarine—Elatrine—Colocynthisine—Byronine—Mudarine—Scillitine—Cathartine—Xanthopierine—Columbine—Quassinine—Lupuline—Lactucine—Ergotine—Porphyroxine—Saponine—Smilacine—Senegine—Guaiacine—Plumbagine—Cyclamine—Peucedanine—Imperatorine—Yanguinine—Meconine—Cubebine, . . . . . Page 524 to 535



## OF ETHERS, AND THEIR COMPOUNDS AND DERIVATIVES.

### OF ETHYL ETHERS.

**f** the oxide of ethyl, common ether, erroneously called sulphuric ether—Of the properties of the oxide of ethyl, and of the means of obtaining it—Of heavy oil of wine; also of light oil of wine—Of Hoffman's anodyne liquor—Of alcohol, or the hydrated oxide of ethyl—Of ethero-sulphurous acid, or sulphurous ether—Of hyponitrite of the oxide of ethyl, called nitric ether, or nitrous ether—Of the process for sweet spirit of nitre—Of the perchlorate of the oxide of ethyl, or perchloric ether—Of acetic ether, or acetated oxide of ethyl—Of oxalic ether, or oxalated oxide of ethyl—Of carbonic ether, or carbonated oxide of ethyl—Formiated oxide of ethyl, or formic ether—Of benzoated oxide of ethyl, or benzoic ether—Of the tartrate and citrate of the oxide of ethyl, and other "salts" of ethyl, so called, of minor importance—Of œnanthated oxide of ethyl, or œnanthic ether, . . . . . Page 529 to 544

**f** *Simple Ethers, formed by the Substitution of another Basacigen Body for Oxygen in the Oxide of Ethyl; or for the Hydrogen in the Water united with that Oxide.*

**f** chloride of ethyl—Bromide of ethyl—Iodide of ethyl—Sulphide of ethyl—Sulphhydrate of the sulphide of ethyl, or mercaptan—Bisulphide of ethyl—Selenide of ethyl—Telluride of ethyl—Cyanide of ethyl, . . . . . Page 545 to 546

**f** *the Dehydrogenation and Oxidation of Ethyl, as contained in Ether or Alcohol, and of the Oxidation of the Residual Products.*

**f** the hydrated oxide of acetyl, called aldehyde—Ammoniated aldehyde, or the hyposacetic of ammonia—Acetal, a compound of aldehyde with ether—Resin of aldehyde—Metaldehyde—Elaldehyde, . . . . . Page 547 to 549

**f** *some interesting Results of the Substitution of Chlorine, Bromine, Sulphur, and other Basacigen Bodies, for the Hydrogen or the Oxygen in the Compounds of Ethyl and Acetyl.*

**f** the chlorohydrate of the chloride of acetyl—Chloride of acetyl—Bromohydrate of bromide of acetyl, Bromide of acetyl, Iodohydrate of iodide of acetyl—Chloroplatinate of chloride of acetyl—Oxychloride of acetyl—Oxysulphide of acetyl—Chloroxalic ether—Chloral, . . . . . Page 549 to 550

### OF METHYL ETHERS.

**f** the oxide of methyl, or methylic ether—Of hydrated oxide of methyl, called pyroxylic, or wood spirit, methylic alcohol—Neutral sulphated oxide of methyl—Acid sulphated oxide of methyl, bisulphated oxide of methyl, sulphomethylic acid—Nitrated oxide of methyl—Of the hyponitrite of the oxide of methyl, or methylic hyponitrous ether—Oxalated oxide of methyl—Formiated oxide of methyl, . . . . . Page 551 to 555

**f** *Reaction of Chlorine, Iodine, Cyanogen, and Sulphur, with Methyl, and its Compounds.*

**f** chloride of methyl—Iodide of methyl—Fluoride of methyl—Cyanide of methyl—Sulphide of methyl—Sulphhydrate of sulphide of methyl, or methylic mercaptan—Perchloride of carbon, . . . . . Page 555 to 556

### OF FORMYL ETHERS.

**f** Compound of hydrated oxide of formyl with oxide of methyl, or methylal—Formiated oxide of methyl—Artificial oil of ants, . . . . . Page 556 to 557

**f** *Compounds of Formyl with Chlorine, Bromine, Iodine, and Sulphur.*

**f** protochloride of formyl—Bichloride of formyl—Perchloride of formyl, chloroform—Chlorohydrate of the chloride of formyl—Perbromide of formyl, bromoform—Periodide of formyl, iodoform—Sulphide of formyl, . . . . . Page 558 to 559

*Of Xylite, or Lignone.*

Mesiten—Mesite—Xylite naphtha—Xylite oil—Methal, . . . Page 559 to 560

## OF THE ETHEREAL COMPOUNDS OF MESITYL, OR MESITYLENE.

Of the chloride of mesityl—Oxide of mesityl—Chloride of pteleyle—Of the nitrate  
oxide of pteleyle—Mesitic aldehyde, or the hydrated oxide of pteleyle,  
Page 560 to 561

## OF AMYL ETHERS.

Of the hydrated oxide of amyl, or oil of potato spirit, or amylic alcohol—Acetate  
oxide of amyl, amylo acetic ether—Of the bromide and iodide of amyl,  
Page 561 to 562

## OF ANIMAL SUBSTANCES.

Indifferent nitrogenized substances common to the vegetable and animal kingdoms—proteine and its modifications,	561
Modifications of proteine,	562
The blood,	563
Brain and nervous matter,	564
Animal secretions and excretions,	565
Bile and biliary calculi,	566
Urine and urinary calculi,	567
Changes which occur during the life, growth, and nutrition of vegetables and animals,	568
<i>Of Respiration,</i>	569
<i>Of Fermentation,</i>	570
Of the saccharine and vinous fermentations,	571
Of the acetous fermentation, a process of acetification,	572
Of the lactic or viscous fermentation,	573
<i>Of the Putrefactive Fermentation,</i>	574

# OF ORGANIC CHEMISTRY,

OR THE

## CHEMISTRY OF ORGANIC SUBSTANCES.

---

5. Under the appellation of organic substances are  
understood—

7. 1st. All those which are created in vegetables  
and animals.

8. 2dly. Such as are generated from those above  
mentioned, either by spontaneous changes, aided by tem-  
perature or catalysis, or by reciprocal reaction.

9. 3dly. Such as arise from the substances created  
as above described, in consequence of their  
union with inorganic bodies.

10. In this department of the science it is, perhaps, less  
difficult to acquire some general ideas, than to make an  
progress in the chemistry of inorganic substances.  
Primitive elements of vegetable and animal matter are  
known and are peculiarly well known. But the light which  
is thrown upon inorganic compounds, by resolving them  
into their ultimate elements, is much more satisfactory  
in many which we can, by the same means, extend to or-  
ganic products. Between these, *ultimate* analysis can de-  
termine little more than a difference in the proportions  
of hydrogen, oxygen, carbon, and nitrogen, of which  
they are constituted; although in their influence on vitality  
they may display the opposite properties of the most de-  
licious food, or the most deleterious poison; of delighting  
our senses in the extreme.

1. Hydrogen, oxygen, and carbon, are the principal  
primitive elements of vegetable substances; especially car-  
bon which is pre-eminently essential to their constitution,  
as has been alleged to perform, in vegetables and ani-  
mal a part analogous to that which silicon performs in  
minerals.

2. In some essential oils, in caoutchouc, in ammonia

in cyanogen, and in some compounds formed or derived from these substances, there is no oxygen, while in oxalic acid, and some other oxides of carbon, no hydrogen exists. But in no instance, excepting that of ammonia, and its hypothetical associates amide and ammonium, is carbon deficient; and in the great majority of instances, the three elements above named are indispensable ingredients. Although, comparatively, nitrogen be found only in a few substances, those into which it does enter are generally pre-eminently active in their properties; and, agreeably to Liebig, without its assistance, vegetation cannot thrive. Hence, as he alleges, it is always to be found in vegetable organs, although not a constituent of many substances which they secrete or excrete.

2093. Magnesium, calcium, sulphur, phosphorus, iron, silicon, bromine, iodine, fluorine, are also found in minute proportions in certain parts of certain vegetable or animal products; and it may be inferred that they perform some useful office; but although subservient, in an important degree, to the functions of animals and plants, they are constituents neither of their organic tissues, nor secretory products.

2094. It is generally a marked distinction, between organic and inorganic products, that the latter can, in a much greater number of instances, be imitated by art.

2095. The incompetency of chemists to regenerate the substances analyzed by them, has caused the accuracy of their deductions to be questioned. Rousseau, having heard Rouelle lecture on farinaceous matter, said he would not confide in any analysis of it, till corroborated by its reproduction from the elements into which it was alleged to have been resolved. I conceive that an acquaintance with facts, thoroughly demonstrable by modern chemistry, would have rendered that ingenious philosopher less sceptical. At first view it may seem reasonable to consider synthesis as the only satisfactory test of the truth of analysis. But if when diamond is burned in one bell glass, and charcoal in another, in different portions of the same oxygen gas, and subsequently, in each vessel, in lieu of the diamond and charcoal, carbonic acid is found, from which, by potassium, carbon may be liberated, who would hesitate to admit both substances to consist of carbon, because this element cannot be recovered in its crystalline form from the gaseous state?

*Of Organic Hydrates.*

1096. It was suggested by Prout, that as, in many vegetable substances, consisting only of carbon, hydrogen and oxygen, the two last mentioned elements existed exactly in proportion for forming water, they might be considered as constituted of water and carbon, and, consequently, as hydrates of carbon.

1097. But it has since been shown, that either the hydrogen of these supposed hydrates, may, in various instances, be supplanted by other elements without separating the oxygen; or that the oxygen may be supplanted without separating the hydrogen.

1098. It is, however, an important and interesting fact, that almost all vegetable substances which are neither oily, nor resinous; such, for instance, as gum, sugar, starch, lignin, hold the elements of water in the ratio requisite to form this liquid, however these elements may be associated.

*the Influence of Heat upon Vegetables, with and without Access of Air.*

1099. When subjected to distillation, vegetable substances devoid of nitrogen, in the first place, yield the water essential oils previously existing in them. At a higher temperature, certain essential oils or spirits, analogous to alcohol, resulting from a new arrangement of the ultimate elements, are in some instances evolved; and either at the same time, or subsequently, at a higher temperature, acetic acid, associated with bituminous or empyreumatic matter, carbonic oxide or carbonic acid, and carburetted hydrogen are generated. By further ignition, the volatile products thus obtained, may be resolved into carbonic oxide and carburetted hydrogen; a deposition of carbon in the solid or pulverulent state, being always a concomitant of the change. In proportion as the hydrogen is raised by heat, its capacity to suspend the carbon appears to be diminished (1259). So far as nitrogen is present, the union of an atom of this element with carbon or hydrogen, ammonia or cyanogen, or some of their compounds, may be generated.

1100. The results above mentioned evidently proceed, to a great measure, from the superior volatility of the

hydrogen and oxygen, which causes them to pass off into the aëriform state, with such portions of the carbon as they may, under these circumstances, be capable of retaining.

3001. The experiments of Sir James Hall show, that vegetable matter, wood for instance, when subjected to heat and pressure, is converted into a bitumen analogous to that of mineral coal. Under these circumstances, caloric destroys the organic structure, but does not sever the constituents of many bodies, which would be otherwise partially dissipated. When ignited in the air, it were almost unnecessary to say that hydrogen, oxygen, and carbon must yield water and carbonic acid only. These are the only products of hydrogen and carbon, when burned where there is an ample supply of oxygen.

3002. By a carefully managed heat several vegetable acids may be converted into acids of a different kind. In some instances, difference of temperature is sufficient to vary the character of the resulting acid.

#### *Of the Ultimate Analysis of Organic Substances.*

3003. The analysis of vegetable and animal matter has been latterly accomplished by heating the substance with oxide of copper, so as to oxidize all the carbon and hydrogen, and liberate, in the gaseous state, any nitrogen which may be present. The hydrogen has been in general estimated from the water produced; the carbon, from the quantity of carbonic acid. Hence the products of the operation have been first passed over chloride of calcium, and afterwards subjected to hydrate of potash, lime-water, or alkaline solutions. The water is estimated from the increased weight of the chloride, and the carbonic acid by the volume absorbed, or the increased weight of the alkaline solution employed for its detention.

3004. By Messrs. Will and Varrentrapp, the proportion of nitrogen in a compound has lately been ascertained by heating it with a mixture of quicklime and hydrate of soda, in a tube of refractory glass. Under these circumstances, the element in question, uniting with hydrogen to form ammonia, is easily secured by means of a dilute solution of chlorohydric acid. The resulting chloride of ammonium is precipitated by chloroplatinic acid, and the resulting salt is washed in a mixture of ether and alcohol. The quantity of nitrogen is estimated by the table of equi-

and by ascertaining the loss of weight consequent exposure to a red heat. Agreeably to the table of elements,  $\frac{1}{2}$  of the loss thus sustained is nitrogen.

. When chlorine is present, chromate of lead is in lieu of the oxide of copper, because the chloride of copper being volatile, would be carried into the cavities intended for the absorption of water and carbonic acid.

. When liquids are to be analysed, small portions are introduced into glass bulbs so as to alternate in a tube of copper, or some other oxidizing agent.

*Mode in which the Ultimate Ponderable Elements of Organic Bodies are associated.*

. As in the analysis of the mineral kingdom, we designate as elementary, those substances which we cannot decompose further, so, in examining organic products, those elements of which the grouping cannot be altered without destroying their most important characteristics, are to be designated as the elementary principles, by which the nature of the compounds is to be understood and described.

. Liebig alleges, that the principal object of organic chemistry, is the investigation of the properties and combinations of organic combinations, and the mode in which the elements are grouped. The idea attached to the word *compound* in this instance, may be illustrated by contemplating the formula of a compound in one way, so as to exhibit the proportions in which each ultimate element enters into it; in another way, so as to make evident not their proportions, but their grouping likewise. Thus the formula  $C^2 O^3$  shows, that two atoms of carbon and three of oxygen enter into the composition of oxalic acid;  $C^2 O^3 \times CO^2$  shows, that this acid is composed of carbonic oxide CO, and carbonic acid  $CO^2$  (556, &c.).

. In like manner, cyanhydric acid may be represented as a compound of two atoms of carbon, one of nitrogen and one of hydrogen,  $C^2 N H$ , or as a compound of carbon and hydrogen,  $C^2 N$  and hydrogen, H, formula,  $C^2 N + H$ .

. The compounds thus cited, CO carbonic oxide, and  $C^2 N$  cyanogen, are considered as acting as compound radicals.

This appellation is employed to designate in these and in others, certain groups of ultimate elements which appeared to be endowed with the power, like simple ultimate elementary atoms, of entering in

combination with one or more of their composing atoms, or of other simple elementary or compound atoms.\*

3011. From a deficiency of better words I shall consider a "compound radical," so called by Liebig, as a compound element, when, like cyanogen or ethyl, it acts as a simple element. I shall restrict the use of the name radical agreeably to the definition in my *Inorganic Chemistry*, to such bodies as do not form the common ingredient of an acid and a base.

3012. Compound elements, like cyanogen, which, when they unite with an anion and a cation, form with the former an acid, with the latter a base, I consider as belonging to the basacigen class (627).

3013. As on the one hand, it is seen that cyanogen performs the part of a basacigen body, or one capable of producing acids and bases, by combining with radicals; so, on the other, we may perceive ammonium, consisting of hydrogen and nitrogen,  $N \times H^4$ , capable like a metallic radical of forming compounds with the basacigen class, which have basic properties in some instances of great energy. But latterly, pursuant to the suggestion of Kane, ammonia is conceived to contain a compound element analogous to cyanogen, consisting of  $NH^3$  which is called amide, and which combines with hydrogen and other radicals, forming compounds called amidurets, capable of union with other definite compounds. Thus it is inferred, that white precipitate consists of amide, mercury and chlorine,  $NH^3 Hg + Cl Hg$ , the symbol of amide is Ad, which being substituted in the above, we have  $Ad Hg + Cl Hg$  for the formula of white precipitate.†

3014. This view of the subject is now generally sanctioned, although neither amide nor ammonium have been isolated.

3015. In fact, it has been shown of late, that there are a

\* Strictly, an element cannot be compound; but chemists, before the idea of compound radicals originated, distinguished compounds capable of entering into combination and of being separated again, and transferred to other compounds, as *proximate elements*, in contradiction to simple elements also called *ultimate elements*. Upon this view of the subject, the ultimate analysis has been understood to convey the idea of the resolution of a substance into its simple elements, in contradistinction to an analysis by which its proximate elements are separated. Alcohol subjected to ultimate analysis would be converted into hydrogen, oxygen and carbon, while by another procedure, it may be resolved into its proximate elements water and ether. I feel myself authorized, under this view, to call those bodies compound elements, which, consisting of more than one element, act like simple elements.

† N is the symbol of nitrogen, H of hydrogen, Cl of chlorine, Ad of amide, Hg of hydrargyrum or mercury (556, &c.).



ber of compound radicals existing in, or arising from, vegetable or animal matter, as capable of uniting with other bodies as do elementary radicals, forming like oxides, chlorides, bromides, iodides, fluorides, cyanides, &c. Of the compounds thus produced, some are the part of a radical in an acid, some an analogue in a base or even of an alkaline base. More acids and bases thus produced, unite similarly to those generated by a union of ultimate elements, which in many cases competent to displace from com-

Compound organic radicals may be divided into two classes accordingly, as capable of forming acids, or not. Hence, they may be distinguished as acidifiable, as basifiable, or as indifferent.

The acidifiable compound radicals are as follows :

	Formula.
oxide or protoxide of carbon,	$\text{C O}$
or bicarburet of nitrogen,	$\text{C}^2 \text{N}$
sesquicarburet of nitrogen,	$\text{C}^3 \text{N}^4$
benzule or benzyl,	$\text{C}^{14} \text{H}^5 \text{O}^3$
or cinnamule,	$\text{C}^{18} \text{H}^8 \text{O}^3$
salicule,	$\text{C}^{14} \text{H}^5 \text{O}^4$
acetule,	$\text{C}^4 \text{H}^3$
formule,	$\text{C}^2 \text{H}$

The basifiable compound radicals are

	$\text{N H}^3$
thule,	$\text{C}^4 \text{H}^5$
methule,	$\text{C}^3 \text{H}^3$
etule,	$\text{C}^{32} \text{H}^{33}$
or glycerule	$\text{C}^6 \text{H}^7$
amule	$\text{C}^{10} \text{H}^{11}$
misitylene	$\text{C}^6 \text{H}^4$
or kacodule	$\text{C}^4 \text{H}^6$

There are likewise some subordinate compound

as with very few exceptions in formulæ expressing the composition of organic substances, only four different symbols requisite, with the figures showing the relative number of atoms, the employment of symbols for that purpose is highly advantageous. The student, therefore,

is advised especially to overcome, by a proper degree of resolution, any repugnance to the study of the formulæ above given, or others which may be resorted to in this or in other modern treatises of chemistry. A comparison of their formulæ, respectively, will convey an idea of the difference in composition existing between the radicals in the preceding list.

3021. Agreeably to Liebig, the term "compound radical" denotes a class of compound bodies possessing the capacity of uniting with the simple elements, and forming, with them, combinations analogous in their properties to combinations of two simple elementary bodies.

3022. From combinations formed as above mentioned, the simple element may be removed and replaced by another element, simple or compound.

3023. According to the same authority, compound radicals are capable of combining with each other, and of forming acids with oxygen, sulphur, or hydrogen.

3024. He assumes that all organic compounds may be arranged in groups, each derived from their appropriate compound radical by the combination of this radical with elementary atoms, and the union of the resulting compounds with other compound bodies.

3025. Under the head of crystallization (494), I adverted to the fact that certain elements may be substituted, the one for the other, without changing the crystalline form. Dumas has latterly held an analogous doctrine respecting the substitution, in organic products, of one element for another, or of a compound radical for an element, without "*altering the general chemical type*," as he calls it; and would have the bodies thus formed grouped together, constituting a natural family. Liebig alleges, that "reciprocal substitution of simple or compound bodies, acting in the manner of isomorphous bodies, should be considered as a true law of nature." This substitution may take place between bodies which have neither the same form, nor any analogy in composition. It depends exclusively on the chemical force, which we call affinity.

3026. In consonance with the law in question, Dumas has found, that in acetic acid chlorine may be substituted for hydrogen, and that in this way a new acid, designated as chloroacetic, may be produced.

3027. This chloroacetic acid is by him alleged to be, in

properties, so analogous to acetic acid, that to know the habitudes of the one, conveys an idea of those of the other.

This analogy he conceives to arise from a chemical law, agreeably to which the properties of a compound depend rather on the type of the composition, than on the particular character of the elements which may have been combined.

8. Berzelius asserts that chloroacetic acid differs from acetic acid in properties, and that the facts adduced justify nothing beyond an opinion, originally expressed upon the subject by Dumas himself, who, speaking of the law of substitution, admitted it to be an "*empirical law deserving our attention only so long as it might hold*

9. It appears to me, that the facts of the cases adduced to in the support of the doctrine of substitution, illustrate them to come under the fourth case of affinity (523), in which two bodies, simple or compound, in union, another body, added in excess, unites with

10. In the case of acetic acid exposed to an excess of hydrogen, there is the affinity between hydrogen and chlorine and that between chlorine and the elements, with which hydrogen is previously combined.

1. Hence results chlorohydric and a new acid, called acetic, in which chlorine may act as a radical, as it is to do in its combinations with oxygen. The existence of chlorocarbonic acid demonstrates that the display of affinity between chlorine and oxides of carbon, is not an accidental property.

2. Either of the classes of radicals abovementioned, may be distinguished into *primitive* and *derived* radicals. Cyanogen, a sesquicarburet of nitrogen, is derived from cyanogen; and acetyl and formyl, from ethyl and methyl.

3. Being convinced that in the present state of chemistry, more even than heretofore, it is best to aim at a general knowledge first, and afterwards to proceed to particulars, I shall not treat of the compounds formed by radicals or products obtained from them, under their particular names, respectively, unless where the substances alluded to have practical importance.

*Of Amide, NH<sup>2</sup>.*

3034. Ammonia, it will be remembered, consists of an atom of nitrogen and three of hydrogen, NH<sup>3</sup>. Amide is assumed to consist of one atom of nitrogen and two of hydrogen, as the formula above given indicates.

3035. The phenomena which ensue when potassium is heated in ammonia, had long been an object of unsuccessful speculation. The metal, when so exposed, becomes converted into an olive-coloured mass, which, by contact with water, is converted into potash and ammonia.

3036. I believe that Dr. Kane was the first to suggest, that in this case the alkalifiable metal takes *the compound radical, amide, from the ammonia*. Thus a compound is generated of amide and potassium. When the amiduret of potassium, produced as described, is presented to water, this liquid regenerates ammonia, by supplying an additional atom of hydrogen to the amide, while the potassium is, by simultaneous oxidizement, converted into potash. It follows that ammonia is an amiduret of hydrogen.

3037. Compounds of amide are called *amides* by Liebig; *amidides* by Kane; though it will be seen, that when combined with hydrogen, Liebig designates the resulting compound as a *hydruret*; in French, *hydrure*. Consistently with the nomenclature which I have employed, the termination in *ide* is restricted to the basacigen class; I shall therefore use the termination in *uret* for the compounds of amide. It is singular that Liebig should use the same word, amide, for the radical and for its compounds.

3038. As by the subtraction of an atom of hydrogen from ammonia, amide is generated, so, by the addition of a like atom, we generate ammonium, of which I have already treated (1106).

3039. Liebig represents amide as acting with hydrogen in the place of an electro-positive radical. Hence, agreeably to his language, ammonia is a "hydrure d'amide," in English, a hydruret of amide; or, more briefly, he calls it hydramide. Of course, consistently, ammonium is a bihydruret, or bihydramide.

3040. The following formula will serve to explain the composition of some of the compounds of amide. It should be kept in mind that Ad is the symbol of amide. White

precipitate is a compound of amiduret of mercury and bichloride,  $\text{Ad, Hg} + \text{Hg Cl}^2$ . Another amido-chloride is formed by the reaction of white precipitate with alkalis, when results a compound of an amiduret with the bioxide and bichloride of mercury,  $\text{Ad Hg} + \text{Hg O}^2 + \text{Hg Cl}^2$ . Two atoms of amiduret of mercury unite with a subsulphate, whence we have a biamido-subsulphate,  $\text{Ad Hg}^2 + \text{O}^3 2\text{HgO}$ . Biamido-sesquinitrate of mercury consists of two atoms of amiduret of mercury, two of acid, with three of bioxide of the same metal,  $2\text{Ad Hg} + 2\text{NO}^5 3\text{Hg O}^2$ . amido-subnitrate, consisting of an atom of amiduret and two of subnitrate,  $\text{Ad Hg NO}^5 2\text{HgO}$ .

3041. White precipitate has been designated as chloramide of mercury: I prefer the name, above employed, of amido-chloride.

*Of Carbonic Oxide as a Compound Radical.*

3042. Of this radical I have already treated as an oxide of carbon. By combining with carbonic acid,  $\text{CO}^2$ , it constitutes oxalic acid,  $\text{C}^2 \text{O}^3$ . This acid, by combining with hydrated ammonia,  $\text{NH}^3 + \text{HO}$ , or more properly with oxide of ammonium, consisting of the same ultimate elements differently grouped (1116), forms neutral oxalate of ammonia, so called. This oxalate is principally used as a test for lime.

3043. *Chloroxycarbonic acid* is a product of the union of carbonic oxide with chlorine, of which some mention has been made (1240).

3044. *Carbamide* is the name given to a compound formed by the union of carbonic acid with amide. It is obtained by mingling chloroxycarbonic acid with ammonia. In this way solid white crystals are produced, consisting of carbamide and chloride of ammonium.

3045. *Oxamide*,  $\text{C}^2 \text{O}^2 + \text{Ad}$ , consists, as may be seen from the preceding formula, of two atoms of carbonic oxide and one of amide. It may be designated as an amido-oxide of carbon.

3046. This compound is obtained in great purity, by decomposing oxalic ether by liquid ammonia, or by heating an oxalate of ammonia in a retort, with a receiver annexed. The oxamide passes into the receiver, and condenses in white flocks. These, being insoluble in water, are depurated by washing with this liquid upon a filter.

3047. Oxamide is described as a brilliant white powder, insoluble in alcohol, ether, and in cold water, but soluble, in a small proportion, in hot water.

3048. Subjected to dry distillation, it is resolved into water, carbonic acid, cyanhydric acid, cyanic acid, and ammonia.

3049. Oxamide differs from the common oxalate of ammonia, consisting of oxalic acid and oxide of ammonium, in having two atoms less water.

3050. Oxalic ether, which may be decomposed instantly by an aqueous solution of ammonia, consists of anhydrous oxalic acid and ether, or oxide of ethyl. The acid yields an atom of oxygen to one of hydrogen to form water, by which the ether is converted into alcohol, while on the one side there remains carbonic oxide, CO, on the other, amide,  $\text{NH}^2$ , which by reciprocal union constitute oxamide.

3051. When oxamide is heated with alkalis or acids, by the accession of an atom of water, oxalic acid and ammonia are generated. The same result ensues from the exposure of a mixture of oxamide and water, to a temperature above the boiling point.

*Of Benzule, <sup>ess</sup>oil, <sup>ess</sup>zoile or Benzyle,  $\text{C}^{14}$ ,  $\text{H}^5$ ,  $\text{O}^2$ .*

3052. The preceding name is given to a compound radical inferred to exist in benzoic acid, and in the essential oil of bitter almonds, giving rise to several interesting compounds. By the addition of an atom of oxygen and an atom of water, it forms crystallizable benzoic acid, which, like many other acids, cannot exist without an atom of water, or some other base.

3053. By the substitution of an atom of hydrogen for an atom of oxygen, benzoic acid is converted into the pure essential oil of bitter almonds,  $\text{C}^{14}$ ,  $\text{H}^5$ ,  $\text{O}^2$ , which Liebig designates as a hydruret of benzule.

3054. By bringing either of the halogen bodies (627), or various acids in contact with this hydruret, with or without exposure to the distillatory process, a variety of compounds may be produced. These compounds, in composition and properties, are somewhat analogous to ethers; inasmuch, as they mix either with ether or alcohol, and retain their radical with an energetic affinity.

3055. The hydruret of benzule does not pre-exist in bitter almonds, but is the product of the mysterious catalyzing

influence of two substances which they contain, amigdalín and emulsin, or synaptase, in an aqueous mixture when subjected to distillation. During the reaction thus induced, cyanhydric acid being generated, endows the resulting oil or hydruret, with a well known poisonous property, which, in the absence of that acid, has been ascertained not to exist.

3056. Benzule forms a compound with amide, called benzamide, by the reaction of chloride of benzule with dry ammoniacal gas; and likewise an acid, by uniting with formic acid, called formobenzulic acid. Hippuric acid, which is the uric acid of the horse, consists probably of benzamide and another peculiar acid; or of hydruret of benzule, with cyanhydric and formic acids.

3057. According to Mr. Alexander Ure, benzoic acid taken internally by man, is discharged in the urine as hippuric acid, the proportion of uric acid undergoing a corresponding diminution.

*Cinnamyl, C<sup>18</sup>, H<sup>8</sup>, O<sup>2</sup>.*

3058. Between this radical and benzule, there is much analogy; since cinnamyl plays a ~~part~~ <sup>part</sup> in pure oil of cinnamon, or hydruret of cinnamyl and cinnamic acid, analogous to that which benzule plays in its hydruret and in benzoic acid. In either case, the substitution of oxygen for hydrogen, converts the hydruret into an acid having the same radical.

3059. Cinnamyl exists in oil of cinnamon, which, when pure, constitutes a hydruret, and in an acid called cinnamic, playing a part similar to that which benzule has been represented as performing in two analogous compounds. In either case, the oily hydruret may be converted into an acid having the same radical, by the substitution of an atom of oxygen for one of hydrogen.

3060. This radical is said to exist in an oil, separable from the balsams of Peru and Tolu.

3061. It does not appear that the compounds formed with this radical are numerous or important.

3062. By the reaction of pure colourless nitric acid with Chinese oil of cinnamon, a crystallized nitrated hydruret of cinnamyl may be obtained,  $C^{18}H^8O^2 + HO + NO^2$ , which by addition of water liberates the pure hydruret of cinnamyle,  $C^{18}H^8O^2$ .

*Of Salicyl, C<sup>14</sup>, H<sup>3</sup>, O<sup>4</sup>.*

3063. This hypothetical radical is inferred to exist in the oil of the spirea ulmaria or queen of the meadow, and in that evolved from a neutral crystallizable substance, called salicin, which may be extricated from the leaves and bark of any species of willow, of which those parts have a bitter taste; and also from some species of poplar. It was originally discovered by Buchner and Leroux, in the bark of the salix helix.

3064. This radical has a great analogy to benzule in properties, as well as proximity in composition, as must be evident from a comparison of their respective formulae. It is in fact benzule plus two atoms of oxygen.

3065. The oil above mentioned has the same relation to salicyl, that the oil of bitter almonds has to benzule, both being hydrurets. The oil of spirea is treated as a hydracid, which it will be well to keep in mind when sourness is insisted upon, as a property peculiar to what are improperly called hydracids.

3066. This hydruret may be obtained in a state which is isomeric, if not identical with that in which it is extricated from the spirea, by distilling one part of salicin with three parts of bichromate of potash, four and a half of sulphuric acid, and thirty parts of water.

3067. It is a colourless, oily, inflammable liquid, with a burning taste; density 1.731, freezing at 4°, boiling at 335.7 when obtained from spirea, but 359.6 as obtained from salicin. It dissolves easily in water, alcohol and ether.

3068. Salicyl, like benzule, forms compounds with the halogen bodies, or with acids, by their reaction with its hydruret. The reaction with ammonia differs from that of benzule, as it unites with the ultimate element, nitrogen, instead of amide.

*Of Ethyl, C<sup>4</sup> H<sup>5</sup>.*

3069. If this be really, as is generally now believed by chemists, the radical in the well known liquid, alcohol, certainly, for good or evil, it is one of the most important and interesting compounds in nature.

3070. In the year 1836, in the last edition of my Organic Chemistry, agreeably to the doctrine prevailing at the time, I treated alcohol as a compound of two atoms of



er and one of etherine,  $C^4 H^4 + 2HO$ . Common ethering from alcohol only in having an atom less of r essential to its constitution, was represented to be monohydrate of etherine,  $C^4 H^4 + HO$ . No change has a place as to the ultimate analysis of these liquids.

only as to the grouping of the ultimate elements-constituents, by which we have in ether,  $C^4 H^4 O$ , in alcohol the formula of ether, with an additional t of water,  $C^4 H^4 O + HO$ . Thus, instead of a *mono-ate of etherine*, ether becomes an *oxide of ethyl*; and iol, from a *bihydrate of etherine*, is transferred into a *ated oxide of ethyl*.

71. Agreeably to either view, the transformation of iol into ether requires only the removal of an atom of r.

72. It is well known that common ether may be obtained by the distillation of alcohol with sulphuric acid, that when, to the materials employed for this purpose, acid, or a salt containing an acid, is added, an ethereal pound of ether with the acid, having more or less analogy with common ether in properties, may be obtained.

73. There is hardly an acid, with which a peculiar r bearing its name has not been formed, such as nitric r, acetic ether, tartaric ether, oxalic ether, muriatic r, &c.

74. The rationale is evident: as to convert alcohol ether, the removal of an atom of water is all that is requisite; to generate any other ether, it is only necessary this oxide, in its nascent state, shall be in contact with acid, or be presented to any basacigen body in union with hydrogen; so that the ethyl may be deoxidized by formation of water, and presented naked to the basacilement.

75. Under this view of the composition of ether, it is accountable, that this oxide will not combine with r, excepting when it is in a nascent state; but this objection may apply also to the existence of etherine as the of the ethers.

76. It does not appear that ethyl has ever been isolated. I have not only distilled pure ether from potassium, without decomposing it, but have likewise cohobated it with potassium in a glass tube, hermetically sealed. lower end, to which the contents naturally subsided,

was kept boiling by a water bath for several days, without being decomposed more than partially. The potassium became coated with a white crust, which being removed, the metal appeared in its metallic state.

3077. The ethereal compounds of ethyl may be classified as forming one order of ethyl ethers.

3078. We have then, in this order, the following classes:—Class 1st. Simple ethers, formed by the union of ethyl with any basacigen element which are named after such element.

3079. In this class we have the

Oxide	}	of ethyl.
Chloride		
Bromide		
Iodide		
Sulphide		
Selenide		
Telluride		

3080. Complex ethers are formed by the union of an acid with any one of these. Excepting those formed with the oxacids and sulphydric acid, there are no ethers in this class. The oxacid ethers may be considered as forming a genus comprising an ethereal compound for almost every acid of importance.

3081. There is only one sulphacid ether, mercaptan, or the sulphhydrate of the sulphide of ethyl.

3082. In consequence of its being obtained by the distillation of sulphuric acid with alcohol, the oxide of ethyl was formerly called sulphuric ether, and is still mentioned under that name in commerce, agreeably to the opinion that it consisted of water and etherine, as other ethers consisted of etherine and an appropriate acid. In the last edition of my Organic Chemistry, I designated this oxide as hydric ether. It is a curious consequence of the change which has taken place, as above described, in the prevailing opinion on this subject, that the name above mentioned is now due to alcohol, which, as respects composition, is, in fact, hydric ether. Yet it differs from ethers in general in having a strong affinity for water in all proportions.

3083. It may be well to premise, that I shall adopt for the oxide of ethyl, when not particularly desirous to recall its chemical composition, the usual name of ether, which

my claim by prescription, however temporarily it may been otherwise designated.

84. As alcohol differs from ether only in the presence of one atom of water, it follows that any chemical reaction, which should effect the removal of that atom, ought to convert it into ether. Yet, excepting the reaction, during distillation, with one or two chlorides, a resort to which could not be found economical, the conversion of one liquid into the other is accomplished by a most complicated and intricate play of affinities, which has been a most productive source of discussion among the most eminent chemists. Nevertheless, this subject is still debateable, notwithstanding that much light has been thrown upon the accompanying phenomena.

85. It may be well for the student to recollect the true composition of these important liquids, and that the conversion of one into the other arises from the substitution of alcohol, mingled with certain acids, to the distillation process.

86. When sulphuric acid is employed as is usual, the result is a combination between two atoms of this acid, one of oxide of ethyl, and one of water, forming what has been called, heretofore, sulphovinic acid, or what Liebig designates as the acid sulphate of the oxide of ethyl.

87. Evidently it would be more properly defined as a double sulphate of ether and water;\* for as, what is called concentrated sulphuric acid, when deprived of water as far as its effect can be produced by ebullition, is a sulphate of ether; sulphovinic acid, consisting of one atom of this acid, and one atom of sulphate of the oxide of ethyl, is a double sulphate of the oxide of ethyl, and wa-

88. So long as the proportion of water present in

the water in hydrous sulphuric acid, has been latterly considered as acting as so that when a metal, by contact with the acid, displaces hydrogen, it is merely in which one radical supplants another. Agreeably to a new doctrine, all sulphur and oxygen present, acts as a compound radical, and, as such, is transferred from one radical to another; but this I think I have shown to be untenable. I resort to refute the Arguments in favour of the existence of Compound Radicals in the Sulphide Salts, 6, 92.

In order to understand the above given explanation, it should be recollected, that the boiling point of diluted sulphuric acid rises, as the proportion of water in it lessens, till it attains the point at which the sulphate of water itself is formed, which is about 600°: also, that the affinity of concentrated sulphuric acid for water is so great, as to enable it to abstract the elements of this liquid from organic substances; in which case they are blackened, and said to be carbonized, in consequence of the evolution of carbon.

the mixture of sulphuric acid and alcohol, is adequate to keep the temperature sufficiently low, the ether, in the double sulphate, being more volatile than the water, existing in excess in the solution, yields the acid to this liquid, and comes over, accompanied by a proportional quantity of steam, and at the outset, of alcoholic vapour. Thus ether, alcohol, and water, being partially removed, the proportion of acid relatively to the residual materials, is increased: but as this takes place, its avidity for water augments, and the boiling point of the mixture rises. In consequence of the increased avidity for water, the acid takes from a portion of the ether,  $C^4H^6O$ , an atom of each of the elements of this liquid,  $HO$ . Thus etherine is evolved,  $C^4H^4$ .

3089. Meanwhile the increased heat causes a portion of the etherine to give up the whole of its hydrogen to a part of the oxygen, of a portion of the acid. Hence sulphurous acid and carbon are evolved; the one being indicated by the carbonaceous colour, the other by its well known suffocating fumes. Under these circumstances, a triple compound, consisting of sulphuric acid and oxide of ethyl, and a portion of undecomposed etherine, being formed, comes over with sulphurous acid and ether, forming a yellow liquid. When this liquid is deprived of its sulphurous acid by ammonia, or any other alkaline base, and the ether is removed by distillation, the residue is the liquid long known as oil of wine, being the efficient and characteristic ingredient of Hoffman's anodyne, erroneously represented in several European works as a mere mixture of alcohol and ether. The preferable mode to isolate the oil of wine, is to expose the yellow liquid, in vacuo, over sulphuric acid in one capsule and slaked lime in another. The sulphurous acid is absorbed by the lime, the ether by the sulphuric acid. The quantity of acid in the oil varies with the mode of isolation; being greatest when the last mentioned mode is resorted to.

3090. The word ether was originally employed to designate a supposed elastic æriform matter, vastly more rare and subtile than air. It is still used in that sense as an appellation for the matter, which is, according to the undulatory theory, the medium by which luminous bodies radiate light. By analogy, the word ether was employed to designate a liquid which bore the same relation to ~~other~~

liquids, as ether proper to air. This appellation has naturally been extended to other liquids analogous in properties and composition. Of ethers in general, common ether may be considered as the best exemplification. What mainly distinguishes the liquids thus called, from alcohol, is their very inferior miscibility with water. Many of them are, however, heavier than water, so that, upon the score of density, they do not merit to be distinguished as etherial.

3091. It will be seen that there are several hydrates, formed with other compound radicals, which are congeners of alcohol in composition, and, to a limited extent, resemble it in properties.

3092. Generally, substances considered as etherial are susceptible of distillation, are inflammable, little soluble in water, but highly susceptible of union with alcohol, essential oils, and resins. They are, for the most part, fragrant and stimulating to the taste, affecting the animal nerves powerfully when inhaled, or swallowed, even in a minute quantity.

### *Of Acetyl, C<sup>1</sup> H<sup>3</sup>.*

3093. The preceding name has been given to a hypothetical sub radical containing the same number of atoms of carbon as ethyl, with three atoms of hydrogen instead of five. This radical is inferred to play the same part, in a liquid lately discovered and called aldehyde, that ethyl does in alcohol. In fact, the only difference in composition existing between these liquids, is that between their radicals; the former being produced from the latter by the removal of two atoms of hydrogen.

3094. Acetyl is chiefly interesting as the radical of the important acid of vinegar, designated by modern chemists as acetic acid. This acid, in the hydrated state, in which alone it is capable of isolation, results from the addition of two atoms of oxygen to aldehyde. By the lesser addition of one atom of the same element, another acid has been made, called acetous acid, or aldehydic acid.\*

\* As both this acid and acetic acid have the same radical, the compound, having the lesser proportion of oxygen, should terminate in *ous* (1052, &c.). Hence the acid in question should be called *aldehydous acid*, if named, so as to show its derivation from aldehyde, and acetic acid should be called *aldehydic acid*; but aldehyde itself enters, as an acid, into an ammoniacal compound, the formation of which is a necessary step in obtaining it in a state of purity. Of course, if these compounds

3095. By Liebig, olefiant gas is treated as a hydruret of acetyl,  $C^4 H^3 + H = C^4 H^4$ , which is just double the quantity of carbon and hydrogen contained in a volume of olefiant gas. But, according to Berzelius, the two atoms of carbon, and two atoms of hydrogen, in a volume of this gas, constitute an independent radical, which he calls *clayl*. Agreeably to Liebig's view, olefiant gas is isomeric with etherine, or etherole, the name given to etherine by him.

3096. Agreeably to the view of the former, the oil resulting from the reaction of olefiant gas with chlorine, is a chlorohydrate of chloride of acetyl,  $C^4 H^3 Cl + HCl$ , while, if the Berzelian idea be adopted, it consists of two atoms of *clayl* and two of chlorine,  $C^4 H^4 Cl^2$ .

3097. When this compound is dissolved in a solution of potash and alcohol, it is decomposed into chlorohydric acid, which forms water and chloride of potassium with the potash, and a compound, which escapes in the gaseous form, consisting of  $C^4 H^3 Cl$ . The composition of this gas is evidently such, that it may be considered as a chloride of acetyl; and its formation must be regarded as confirming the view taken by Liebig of the composition of the oil of the Dutch chemists. Bromine, like chlorine, on being presented to olefiant gas, produces a compound, which may either be considered as a bromohydrate of the bromide of acetyl, or simply as a bromide of *clayl*, in other words, of olefiant gas; but which, by reaction with the alkalies, evolves a gas, the composition of which, it would seem, can only be reconciled with the idea of a bromide of acetyl. The action of iodine is analogous, but not so well ascertained. The product is pulverulent in its consistency, but in other respects resembles that which results from the reaction of chlorine with olefiant gas.

*Of Mesityl or Misitylene,\*  $C^6 H^4$ .*

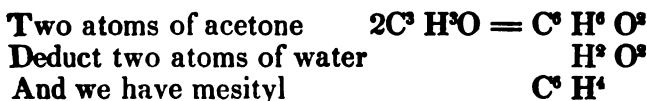
3098. The vapour of pure acetic acid, in passing through a red-hot porcelain tube, is decomposed, yielding a colour-

be all considered as oxacids of acetyl, as I think would be more proper, agreeably to the nomenclature adopted in analogous instances, their names would be *acetic acid*, *acetous acid*, and *hypoacetous acid*. But aldehyde, as a congener of alcohol, is, perhaps, preferably designated as a hydrated oxide of acetyl.

\* Liebig does not introduce this radical into his general list of radicals, but treats of it as a product of the decomposition of acetyl. The same course is pursued in respect to *kacodyl*, although this contains, as will soon appear, arsenic, an element which does not exist in acetyl. It will also be found that he places *sugars* under *ethyl*, as yielding *ethyl* by their decomposition. This does not appear to me judicious, because, by the same rule that *mesityl* is placed under *acetyl*, *ethyl* should come

s, limpid, volatile, inflammable, empyreumatic liquid, which has received the name of acetone. This liquid may be obtained, also, by dry distillation, from any dry acetate of an alkali or alkaline earth; also by heating sugar of lead with quicklime, by means of an iron bottle. When acetone is distilled with half its volume of fuming sulphuric acid, upon the liquid which passes into the receiver a yellow oil swims, which, after being washed with water, is rectified. The first portions contain a little acetone, which is removed by redistillation, by means of a water bath.

3099. This oil is mesityl, being a colourless, oleaginous, inflammable liquid, having a feeble odour, recalling that of allylic. It is lighter than water. With alkalies it undergoes no change. With sulphuric acid, nitric acid, and chlorine, its habitudes resemble those of benzole. Its composition is equivalent to two atoms of acetone, less two atoms of water.



4000. Acetone was inferred to be an hydrated oxide of mesityl; but Dr. Kane, the author of the inference, has admitted that there are not sufficient grounds to justify him in retaining that idea of its composition. Acetone possesses peculiar and useful powers as a solvent. Many salts which are soluble in both alcohol and water, are insoluble in acetone, especially chloride of calcium and hydrate of potash. It burns with white flame, and has nearly the same density as alcohol. Its taste is disagreeable, having some analogy, however, with that of peppermint.

4001. Metascetone,  $C^6 H^5 O$ , is the name given to a colourless, volatile, fragrant, inflammable liquid, soluble in alcohol and ether, but insoluble in water, and which boils at 2.5. It may be considered as two atoms of acetone, minus one atom of water,  $C^6 H^6 O^2 - HO = C^6 H^5 O$ , metascetone.

4002. This liquid is generated simultaneously with acetone, when one part of sugar, and eight parts of powdered quick-lime, are subjected to distillation.

For sugar. But where a radical only furnishes the elementary ingredients to either compound, or derives its ingredients from one, I do not conceive that any connexion in classification should be made between it and the substances whence it is obtained, or to the formation of which it contributes.

4003. Mesityl forms various compounds with the basigen bodies, which it is not deemed proper to describe here. With sulphuric acid it forms a compound which affords soluble salts with baryta and lime.

*Reflections on the Relation or Analogy between Acetyl, Ethyl, Amide, and Ammonium.*

4004. By the addition of an atom of water, HO, to ammonia,  $\text{NH}^3$ , an oxide of ammonium is produced,  $\text{NH}^4\text{O}$ , which is the base of ammoniacal oxysalts (1116). In like manner it was supposed by Boullay and Dumas, that by the acquisition of an atom of water, etherine, a hydruet of carbon (1267), was enabled to play the part of a base in the neutralization of oxacids. This idea was, for some time, generally sanctioned, and hence, in the last edition of this Compendium, etherine was represented as the base of all the ethers which have, in this edition, been represented as having ethyl as their radical, and its oxide for their base.

4005. It has already been mentioned (1109), that agreeably to the doctrine advanced by Berzelius, and generally adopted, in the salts formed by presenting ammonia to liquid acids, the elements of the resulting base exist, not as a hydrate of ammonia, but as an oxide of ammonium. So far as an analogy with the habitudes of ammoniacal compounds would influence the view adopted, a corresponding conception would be created, that in etherial compounds the base should be an oxide of ethyl, not a hydrate of etherine. Besides the correspondence thus existing, there was no small analogy between the relation borne by amide to ammonium, and acetyl to ethyl: the only discordancy being, that the susceptibility of forming acids, displayed by acetyl, has not been observed in amide.

*Of the Compound Hypothetical Radical, Kacodyl,  $\text{C}^4 \text{H}^8 \text{As}$ , Symbol Kd.*

4006. The substance to which the name above mentioned has been given, is one of the many compound radicals of which the existence has lately been inferred by chemists. It has the unusual feature of containing, among its essential constituents, an atom of a metallic radical, arsenic. Its name is from  $\kappa\alpha\kappa\omicron\varsigma$ , bad, and  $\acute{o}\delta\omicron\rho\omicron\varsigma$ , odour.

4007. The protoxide of kacodyl constitutes a fetid, virulently poisonous, etherial, spontaneously inflammable, vola-



tile, limpid liquid, long known as the fuming liquor of Cadet, its discoverer. This liquid, now called alcarsin, is obtained by distilling dry acetate of potash with an equal weight of arsenious acid. By digesting alcarsin, or oxide of kacodyl, in chlorohydric acid, chlorine taking the place of oxygen, a chloride of kacodyl results. From this the radical is separated, by reaction with metallic zinc, at the temperature of  $230^{\circ}$ , and removing the resulting chloride of zinc by water.

4008. Kacodyl is an etherial, limpid, spontaneously inflammable liquid having a nauseous odour. It sinks in water without dissolving, but is soluble in alcohol or ether. It boils at  $338^{\circ}$ . At a red-heat its vapour is resolvable into arsenic, olefiant gas, and light carburetted hydrogen.

4009. The following compounds are formed by this radical, of which it does not appear consistent to treat particularly here.

Kd O	Alcarsin	Oxide	} of kacodyl.
Kd Cl	Chlorarsin	Chloride	
Kd S	Sulpharsin	Sulphide	
Kd Cy	Cynarsin	Cyanide	
Kd O <sup>3</sup> + HO	Alcargen	Hydrated trioxide	

4010. Agreeably to the preceding formulæ of the compounds of kacodyl, it may be seen that, excepting alcargen, they differ, in composition, only as respects one of their ingredients, a basacigen element, to the presence of which they owe the diversity of the names given in one of the lists.

4011. Alcargen, or kacodylic acid, differs from the rest in holding an atom of water, HO.

4012. Liebig supposed the bodies in question each to consist of an atom of acetyl and an atom of arsenuretted hydrogen, As H<sup>3</sup>, not grouped into one radical; but Berzelius suggested that they were so grouped, and this Bunsen has proved to be true, by isolating kacodyl as above described.

4013. It may, however, be well to point out, that the composition of kacodyl is consistent with the idea of Liebig, since an atom of acetyl, - - - C<sup>4</sup> H<sup>3</sup> and an atom of arsenuretted hydrogen, - As H<sup>3</sup> are equivalent to an atom of kacodyl, - C<sup>4</sup> H<sup>6</sup> As

4014. I object to the unmeaning names above given, as not conveying any idea of composition. Hence I shall use those which indicate the composition.

4015. Alcargen, more significantly called kacodylic acid, or hydrated trioxide, agreeably to the nomenclature which would make hydrous sulphuric acid a sulphate of water, would be a kacodylate of water.

*Of Methyl, C<sup>2</sup> H<sup>3</sup>.*

4016. After it had become evident that the etherial compounds, derived from the reaction of alcohol with acids or halogen bodies, had all a common compound radical, chemists were naturally led to infer, that there might be other series, similar in their nature, having the same electro-negative ingredients united with other compound radicals. These speculative inferences first received a practical verification, from the labours of Dumas and Peligot respecting the composition and combinations of pyroxilic spirit, obtained from the products of the destructive distillation of wood or other organic products. From the investigations of these chemists it has been made evident, that pyroxilic spirit is the alcohol of a series of compounds having methyl as a radical.

4017. The compounds of methyl with the basacigen class, and those formed between its oxide and acids, are produced by reactions with methylic alcohol or ether, or their products, similar to those by which analogous compounds with ethyl are effected. There is, likewise, a great analogy in the properties of the two series; yet methylic ether (or in other words the oxide of methyl the compound which is the congener of ether proper), is gaseous, in lieu of existing like ether as a liquid. Moreover, a nitrated oxide of methyl, or a true methylic nitric ether, is readily generated when wood spirit (hydrated oxide of methyl), is presented to nitric acid. This etherial compound, has no congener among those of ethyl, because the reaction, between nitric acid and alcohol, is attended by a reciprocal decomposition, by which hyponitrous acid is evolved and combines, while nascent, with oxide of ethyl, existing in an undecomposed portion of the alcohol. Hence it arises, that hyponitrous ether is generated instead of nitrated oxide of ethyl. On the other hand no hyponitrite of the oxide of methyl, results from the reac-

ion of nitric acid with wood spirit; since the decomposition, requisite to the development of hyponitrous acid, does not ensue. Consequently, Liebig alleges that no congener of hyponitrous ether exists among the etherial compounds of methyl.

4018. I have recently been enabled to fill up this interval in the methyl series, by subjecting wood spirit to a hyponitrite, in contact with a diluted acid.

### *Of Formyl.*

4019. Formyl has a relation to methyl, similar to that which acetyl has to ethyl. In either case, there is a radical differing from another, only by the subtraction of two atoms of hydrogen.

4020. The hydrated oxide of formyl is inferred to exist in a liquid, obtained by the reaction of two parts of wood spirit with three of sulphuric acid, three of water, and two parts of peroxide of manganese. An inflammable, etherial, colourless liquid, of an agreeable aromatic odour and susceptible of solution in three parts of water, was thus procured. This liquid has been inferred to be a compound of two atoms of oxide of methyl, and one of hydrated oxide of formyl.

4021. There are in the formyl series no compounds corresponding to aldehyde, or acetic acid. The only oxide is that long known as formic acid, from its having been first obtained from ants. This acid is obtained from formyl, as acetic acid from acetyl, by the addition of three atoms of oxygen.

4022. Agreeably to Liebig, three chlorides of formyl have been isolated. The perchloride has been known for a good while, having been obtained by distilling alcohol with hypochlorite of lime. It was obtained about ten years since in this country by Gurthrie, and for some time confounded with the etherial oil of olefant gas, which is now considered by Liebig as the chlorohydrate of the chloride of acetyl.

### *Amyl, C<sup>10</sup> H<sup>11</sup>.*

4023. A peculiar liquid was noticed by Scheele to accompany potato spirit. Subsequently, by Pelletier, Cahours and Dumas, it was inferred to be the hydrated oxide of a peculiar compound radical, to which the name at the

head of this article was given. It follows that this liquid must be a congener of alcohol, its formula being  $C^8 H^8 + HO$ .

4024. The amyl series of compounds corresponds with those of other radicals to a certain extent, but is upon the whole very incomplete, having no oxide to occupy the place of a congener of ether. Even the chloride does not appear to be permanent per se. The bromide and iodide are more enduring, and in their habitudes somewhat analogous to corresponding combinations in the series of other radicals.

4025. Yet in the case of sulphoamylic acid, the analogy is well supported to other etherial double sulphates, such as sulphovinic acid, and there have been formed sulphoamylates capable of decomposition and of reproducing the hydrated oxide, potato spirit.

4026. An amylic acetic ether has been produced, by distilling two parts of acetate of potash, one part of potato spirit, and one part of sulphuric acid. As respects inflammability, volatility and insusceptibility of mixture with water, the amylo acetic ether is truly etherial in its nature.

4027. By the substitution of two atoms of oxygen for a like number of hydrogen, effected by treating potato spirit with hydrate of potash, a change in composition arises analogous to that by which alcohol is converted into acetic acid. An acid is in this way created, called valerianic, in consequence of its being identical in properties and composition with that extricated by distilling water from the root of valerian.

4028. This acid was produced, also, by causing potato spirit to fall slowly in successive drops upon platinum black duly heated. Peculiar liquids, somewhat etherial in their properties, have been evolved from potato spirit, of which the one  $C^{20} H^{17} Cl^3 O^2$  seems to be a congener with chloral, the other with olefiant gas the hydruret of carbon of Liebig.

### *Glyceryl, $C^3 H^7$ .*

4029. The wonderful fabric of scientific knowledge for which we are indebted to the skill, sagacity and ingenuity of modern chemists, is formed in part of materials which are altogether new, and in part of such, as although long known, owe nearly all their present theoretic value to the

hich they have latterly been made to answer in the fabric to which I have alluded.

2. In the preceding account of the amyl series it is noticed, that a liquid long since distinguished by its name, and known under the name of oil of potato spirit of potatoes, has latterly been dignified with a place among the congeners of alcohol.

1. In glycerine,  $C^6 H^7 O^5 + HO$ , the hydrated oxide compound radical *glyceryl*, we find, in like manner, a compound of similar antiquity, and, as respects its discovery, of like origin; having been well known since the time of Scheele, as the sweet principle of oils. For the place which it now occupies, the scientific world is indebted to Chevreul and Pelouze.

2. Anterior to the labours of Chevreul, an erroneous opinion existed that the process of saponification consisted in nothing more than a union between the alkali and oil; but it was deemed to be a case simply of combination. The existence in every oil of an electro-negative, and an electro-positive ingredient, the one performing the part of a base, the other of an acid, was not imagined.

3. The oxide of glyceryl is the base common to a great variety of vegetable and animal fixed oils, whether liquid or solid in state, denominated fat, being liberated during the saponification of those substances with fixed alkalies, as in the process of saponification. It is best prepared by saponifying oil of olives with litharge, separating the resulting soap of glycerine, and precipitating any dissolved lead by hydric acid (897, 899).

4. Glycerine is said to be deficient of two properties common to its alcoholic congeners, solubility in ether, and susceptibility of distillation without decomposition. It is colourless, and inflammable; of the density of being about one-fourth heavier than water.

5. It does not appear that there are any other important compounds formed with this radical by the bases or acids, so as to be productive of compounds congeneric with those so formed by most of the other etherifiable compound radicals. There is, nevertheless, a congener of sulphovinic acid in sulphoglyceric acid, properly called the double sulphate of the oxides of glyceryl, and of hydrogen.

*Cetyl*,  $C^{22}H^{44}$ .

4036. *Of cetyl* it may be sufficient to say, that it is perfectly analogous as respects the part which it performs in spermaceti, with that performed by glyceryl, as the radical in the base of the fixed oils generally.

4037. The diversity of such oils, in other cases, is produced by variation in the acids with which the oxide of glyceryl in them severally is combined. Spermaceti has been represented as a solitary instance in which a change of properties results in a concrete fixed oil, from a peculiarity in the hydrated oxide constituting the base, while the acids, combined with this base, are those which have been described as entering into the composition of oleaginous products in general. Recently, this view of the subject has been controverted by Smith. *Silliman's Journal*, October, 1842. (See 5055, page 426.)

4038. The hydrated oxide of cetyl,  $C^{22}H^{44}O + HO$ , may be elaborated from spermaceti by saponification, in a mode resembling that by which glycerine is obtained. It has been designated by the name ethal, a word made up of the initials of alcohol and ether. It differs from other alcoholic hydrated oxides, in being deficient of that solubility in water which is one of the most striking and distinguishing attributes of alcohol proper. It differs also in being solid until heated to  $118^{\circ}$ . The analogy with glycerine fails as respects taste, being insipid; also in this, that glycerine is soluble in water, and insoluble in ether.

4039. Cetyl has not been isolated; but by repeated distillation with anhydrous phosphoric acid, ethal has been made to yield an inflammable liquid compound,  $C^{22}H^{44}$ , having to it a relation analogous to that which etherine or etherole,  $C^4H^8$ , has to ethyl,  $C^2H^4$ . Cetene, as this liquid is called, seems to be of the nature of an essential oil, since it may be distilled. It requires, however, the high temperature of  $527^{\circ}$  for this purpose.

4040. Cetyl coincides in habitudes with the other compound radicals of this class, as respects the formation of double sulphates, analogous to the sulphovinates. It also forms a chloride capable of being distilled, and by the substitution of three atoms of oxygen for two of hydrogen, is converted into an acid, denominated ethalic,  $C^{22}H^{42}O^2$ , which is a congener of acetic acid.

## OF NUTRITIOUS VEGETABLE SUBSTANCES DEVOID OF NITROGEN.

4041. Under this head I place gum, sugar, fecula, and lignin. Immediately, this last mentioned substance is rather food for worms than for man; but it will be seen that lignin may be converted into sugar.

4042. The substances above enumerated might be treated as hydrates of carbon, agreeably to the suggestion of Prout (2096), were it not that their properties do not warrant the idea, that the hydrogen and oxygen are more intimately allied to each other, than to the carbon.

*Of Gum.*

4043. Substances known under the generic name at the head of this article have certain properties in common, but vary with the tree by which they are generated. Some, like gum arabic, or gum senegal, are perfectly soluble in water; while others, like tragacanth, are capable only of forming a paste with the same liquid. Those of the first mentioned kind are susceptible of rapid desiccation and induration, by access of atmospheric air, while the others give up water, comparatively, with reluctance. They are all distinguished from resins, which they resemble externally, in being insoluble in alcohol, ether, or essential oils. They differ from sugar in the want of sweetness, and from starch in not being coagulable by heat.

4044. Guerin, in an elaborate treatise on gums, divides them into three classes:—1. *Arabin*, of which gum arabic is the type, soluble in cold water. 2. *Bassorin*, which swells into a jelly, but does not dissolve in water: gum bassora, or tragacanth, may exemplify this class. 3. *Cerasin*, from the gum of the cherry-tree. *Cerasin* is also insoluble in cold, but soluble in boiling water, and when treated with nitric acid, gives about *one-fourth* less mucic acid than bassorin.

4045. Of *arabin*, by his analysis, the formula is  $C^6 H^5 O^5$ . Gum senegal, and the soluble parts of gum tragacanth and bassora gum, consist of arabin.

4046. Of *bassorin* the formula is  $C^{10} H^{11} O^{11}$ .

4047. *Cerasin* appears to be metamorphic arabin; for it has precisely the same composition, and is changed into it by solution in boiling water. The gums of the cherry, apricot, prune, peach, and almond tree, are of this kind.

4048. Berzelius employs the word mucilage to designate that species of matter which is exemplified by the bassorin of Guerin. Varieties of this kind of gum are seen in infusions of flaxseed, of slippery elm, and pith of sassafras. This use of these terms is not adopted by Turner, Kane, or Graham. The principal difference between gum and mucilage, agreeably to general acceptance, seems to be, that mucilage is not susceptible of spontaneous hardening by desiccation. Graham admits only of two genera of gums, exemplified by gum arabic and gum tragacanth. By Kane, they are treated of under three heads—arabic, cerasin, and dextrine, or artificial gum. This last mentioned variety is obtained from starch, and does not appear to have higher pretensions to be ranked as a gum, than the modification of starch by heat, known as British gum. Substances which come under the name of gum, agree in general properties; yet there are scarcely any two which are quite similar. Gum arabic is deemed to be the most perfect specimen of the substances bearing the name.

4049. Berzelius considers the reaction of a solution of this substance with a solution of the silicate of potash, as the most striking characteristic of its properties. One portion of it forms, with one part of the alkali and all the acid, a triple compound, which precipitates; while another portion of the gum, and the remainder of the potash, combine and remain in solution.

4050. Gum arabic differs from other gums in combining with the sesquioxide of iron, and forming a compound insoluble in water, but soluble in acids. A solution of gum arabic in 1000 parts of water, being mixed with a solution of the sesquioxide of iron, yields, in 24 hours, a yellow precipitate. This species of gum also combines with, and precipitates the protoxide of mercury from the nitrate. There appears to be no important difference between gum senegal and gum arabic.

### *Of Sugars.\**

4051. Under this head I would place two genera of substances; crystallizable sugars, and syrups incapable of

\* Liebig treats of sugars under the general head of an "appendix to the combinations of ethyl and acetyl." His commentator, Gregory, alleges that they are "thus treated of, since from them are derived all the compounds of ethyl; and, also, be-



crystallization, and which might be called suavin. Of the former, sugar candy, and the crystals found in raisins and honey, are specimens. The latter are exemplified by the uncrystallizable syrups of raisins and of honey; also the sweet matter of the sweet potato, and the uncrystallizable syrup of the sugar cane, known as molasses.

4052. The qualities, both of crystallizable and uncrystallizable sugars, vary with the plants from which they are produced. In the power of imparting sweetness to infusions, the crystallizable sugar of the cane is pre-eminent.

4053. As sugar has been found to be very susceptible of yielding alcohol by fermentation, this property has been made the basis of defining the meaning of the word, so that every substance capable of the process alluded to, is to be considered as sugar, whatever may be its taste, or however it may differ in its properties from the substances usually called by the name.

4054. Thus the fermentable "*wort*" of distillers or brewers, the uncrystallizable juices of fruits, a substance found in mushrooms or ergot, also an insipid matter found by Thenard in diabetic urine, are all to be considered as consisting of sugar, so far as they are capable of yielding alcohol by fermentation.

4055. I am reluctant to employ words in a sense different from that in which they are generally understood. Agreeably to usual acceptation, sweetness is an indispensable attribute of sugar. *Sugary* and *sweet* are synonymous. "*As sweet as sugar*" has long been an expression conveying the idea of superlative sweetness.

4056. Chemists have erred, I think, in assuming that

cause the uncertainty in which we are as to their true constitution, renders it impossible to arrange them on scientific principles."

That ethyl compounds are derived from sugars, might be a reason for treating of them under sugars; but I cannot perceive the converse to be true. But as aldehydes or acetous acid, and acetic acid, are placed under the head of acetyl, and the compounds of mesityl are derived from acetic acid, a compound not necessarily derived from sugar, if the reason above given were sufficient for placing sugars under ethyl, it is, on that same ground, improper to place them under acetyl, since this radical is not necessarily a product of sugar.

In reply to the last sentence quoted, it might be demanded, why inability to arrange sugars upon scientific principles, justifies their being placed under the head selected, in preference to any other: whether every set of substances which cannot be arranged on scientific principles, are to be discussed under the joint head of combinations of ethyl and acetyl?

The best justification which occurs to me for any connexion between cane sugar and acetyl is, that when anhydrous it is isomeric with acetyl, one atom containing three of this radical, acetyl,  $C^3 H^3 + 3 = C^{12} H^6 O^6$ .

nothing besides sugar is susceptible of the vinous fermentation. The conversion into alcohol of the insipid product of diabetes, which has been treated as sugar, because proved to be susceptible of the process in question, might with more propriety, as I conceive, be deemed to demonstrate that this process may be undergone by substances which are not sufficiently of a saccharine nature to merit the name of sugar.

4057. According to Kane, after cane sugar has been subjected to a ferment, at a certain time before its conversion into alcohol, it affects polarized light in the same way as grape sugar. Hence it is inferred, that cane sugar is not directly susceptible of the vinous fermentation; and that of all sugars, that of the grape only is capable of immediately undergoing that process. It follows, that if the contested definition be not disregarded, the sweet crystallizable matter extracted from the cane, hitherto considered as the most perfect of the sugars, must be deprived of its title, and occupy a place on a level with starch, as being, like this substance, incapable of the vinous fermentation, without a previous transformation into grape sugar.

4058. Liebig enumerates the following varieties of sugar. *Cane sugar, grape sugar, lactin or sugar of milk, uncrystallizable sugar, and sugar of mushrooms.* To these Graham adds, *insipid diabetic sugar, manna sugar or mannite, and liquorice.*

4059. As a good account of the sources of the sugar of commerce, and the means by which it is elaborated may be found in the United States' Dispensatory, it will be doubly inexpedient to extend in this treatise the information given, beyond its chemical composition and habitudes.

4060. Of cane sugar, perfect specimens are seen in the best double refined sugar, and in colourless sugar candy. Its specific gravity is 1.6. At 350° it fuses into the well known form of barley sugar, which, by exposure to air, is alleged to become white, opaque, and crystalline.

4061. Exposed to the temperature of 650°, by losing an atom of water besides that of crystallization, sugar is transformed into the dark brown substance called caramel. Thus obtained, caramel is not entirely exempt from undecomposed sugar and other impurities, but may be freed from them by solution in water, and precipitation by alco-

1. The precipitate thus created, when dried, forms a black or dark brown powder, which may be redissolved in water. It is insipid, not fermentable, and neither acid nor alkaline. Caramel is used to deepen the colour of fermented or spirituous liquors. During its decomposition heat, fumes are emitted by sugar, which not only disseminate, but, as I believe, neutralize fetid emanations. For solution, cane sugar requires one-third of its weight of distilled water, but the effect of this liquid at a high temperature, is rather that of lowering the point of fusion, than acting as a solvent; since, at the temperature of  $350^{\circ}$ , sugar liquefies per se, and of course may liquefy with the slightest proportion of water which can be added. Hence the liquefaction is due to heat rather than to water.

1062. If a concentrated solution of sugar be subjected, for some time, to the temperature requisite to vaporize the excess of water, under the whole pressure of the atmosphere, it is changed by degrees into uncrystallizable sugar. Recently, of late years, the vaporization is aided by a reduction of atmospheric pressure, by means of an air pump. (12.)

1063. Sugar combines with some salts; and acts feebly as an acid, so far as to unite with some bases. In the soluble compound, formed by anhydrous sugar with oxidized lead, the base is a dioxide. With one atom of barium, sugar forms a crystalline compound; with common salt it forms crystals readily soluble in water.

1064. Berzelius alleges that an aqueous solution of sugar dissolves the carbonate and subacetate of copper, giving rise to a green liquid, from which the metal is precipitated by sulphydric acid, or cyanoferrite of potassium, but not by alkalies. When boiled with solutions of cuprous salts, it causes the reduction of the copper.

1065. Several products are obtained by the reaction of various acids, either dilute or concentrated, with the various kinds of sugar; also by their reaction with alkalies. These products being complicated in their nature and of little practical utility, I shall not treat of them here.

#### *Grape Sugar.*

*Crystallized*,  $C^{12} H^{14} O^{14}$ ; *Anhydrous*,  $C^{12} H^{12} O^{12}$ .

1066. Crystals of this sugar may be seen in raisins, in which it is called candied sweetmeats, and in honey, in either

of which it forms the least fluid portion. Fruits generally owe their sweetness to its presence. The sugar formed from starch by digestion with diastase, or sulphuric acid, is of this species; and also the sugar of diabetes.\*

4067. Grape sugar may be obtained in crystals from grape juice, by neutralization with chalk, clarifying with albumen, evaporation, and subsequent repose: also from diabetic urine, by evaporation to dryness, by means of a water bath, washing the resulting crystalline mass on a filter with cold alcohol until it becomes white, and repeated re-solution and recrystallization.

4068. It is remarkable, that notwithstanding the analogy between cane and grape sugar, they differ much in their chemical qualities, as shown by their habitudes with chemical reagents. Strong mineral acids, which react but feebly with grape sugar, readily decompose cane sugar. With alkalis an opposite result ensues. The compounds which are formed by these sugars respectively, with bases, are quite different.

4069. From an alcoholic solution, grape sugar crystallizes in transparent square tables or cubes; from an aqueous solution, it consolidates into a spongy mass of crystalline grains.†

### *Sugar of Milk, or Lactin.*

4070. The formula of crystallized sugar of milk is  $C^{24}H^{24}O^{24}$ , or  $C^{24}H^{19}O^{19} + 5HO$ . By a heat of  $248^{\circ}$  it loses two atoms of water, and by  $302^{\circ}$ , five atoms. (Berzelius.) It is obtained by evaporating the whey of milk, and purifying the first crystalline product by animal charcoal and recrystallization. It forms white, semi-transparent, quadrangular prisms, which have the density 1.543. They are soluble in five or six parts of cold water, and in two and a half parts of boiling water. The taste of the crystals is very feeble, being inferior, in sweetness, to that of their solution. Sugar of milk is unalterable in the air, or by a heat under  $212^{\circ}$ , and is insoluble in alcohol or ether. When milk is exposed to a temperature of from  $95^{\circ}$  to

\* Dumas has proposed that grape sugar be called glucose; but as Liebig alleges that all sugars, even that of the cane, have to be converted into grape sugar in order to be rendered susceptible of the vinous fermentation; it would seem, consistently with the received definition of sugar (4053), as if cane sugar should be called glucose, yielding the name of sugar to the sweet matter of the grape.

† See fermentation; also (4071).

it undergoes the vinous fermentation, generating alcohol, while its sugar disappears. But it is presumed that matter is converted first into grape sugar, probably by the influence of the free acid, which, being formed, sweetens the milk. Milk sugar forms two compounds with oxide of lead, of which the formulæ are  $C^{24} H^{19} O^{19} + 5PbO$ ,  $C^{24} H^{19} O^{19} + 10PbO$ . (Berzelius.)

### *Mushroom Sugar.*

71. This sugar, of which the formula is  $C^{12} H^{13} O^{12}$ , according to an analysis by MM. Liebig and Pelouze, was obtained by M. Wiggers, by subjecting the tincture of ergot of rye to water. It is crystallizable and soluble in water and alcohol, but insoluble in ether. Mushroom sugar is also fermentable by yeast, and diffuses the odor of caramel when carbonized by a high temperature. The only property by which this sugar is distinguished from the ordinary species is, that it does not throw down a precipitate of copper from a boiling solution of the acetate.

### *The Fermentable Matter of Diabetes, called Insipid Sugar.*

72. It has been stated (4052), that a substance was obtained, by Thenard, from the urine of diabetes insipidus, and subsequently, by Bouchardat, from the same source, which was insipid, or only faintly sweet. The aqueous solution of this sugar was fermentable by yeast, and susceptible of being converted into the sugar of grapes by disulphuric acid.

### *Liquorice Sugar.*

73. The inspissated juice of the root of the *Glycyrrhiza glabra* contains a species of unfermentable sugar, which may be obtained by clarifying the juice with albumen, precipitating the sugar with sulphuric acid, washing the precipitate with water, dissolving it in alcohol, which dissolves some undissolved albumen, and then decomposing the sulphate of liquorice sugar by carbonate of potash.

After evaporation, the sugar remains as a yellow translucent mass, cracked in all directions, and easily detached from the vessel in which it has been desiccated. Liquorice sugar is capable of forming soluble or sparingly soluble compounds, with both the mineral and vegetable acids. It also combines with bases.

*Manna Sugar, or Mannite.*

4074. The formula of manna sugar is  $C^6 H^7 O^6$ , according to the analysis of Oppermann and of Liebig. Manna is in oblong globules or masses, of a yellowish-white colour, being an exudation from various trees, principally the *fraxinus ornus*, and *encalyptus mannifera* of New South Wales. It exists also in the juices exuded by cherry and plum trees, in those of various kinds of mushrooms, and of celery and other roots. Manna sugar may be prepared by dissolving the manna of the shops in boiling alcohol, and allowing the solution to cool. It may be purified by repeated crystallizations. Mannite crystallizes in slender, colourless, four-sided prisms, of an oily lustre. It has a slightly sweet taste, forms, with water, a solution which is not fermentable. It is anhydrous, and may consequently be heated to redness, without any loss of weight. Its aqueous solution dissolves oxide of lead. Nitric acid converts mannite either into oxalic, or saccharic acid; but not into mucic acid. Mannite is also one of the products of the vinous fermentation of cane, or grape sugar.\*

*Fecula, or Starch.*

4075. A substance, of which starch is a good specimen, and of which the generic name is fecula, may be obtained from the meal or flour of grain, and from the tubers of the potato, and various other vegetables. It is found in commerce under the names of sago, tapioca, arrow-root, &c. Of the sources of these varieties of fecula, an excellent account is given in the United States Dispensatory. It is more or less a constituent of vegetables in general. When the farinaceous matter, procured from such sources by rasping or grinding, is washed, the fecula is suspended, and subsequently deposited. Where there is vegeto-animal matter, as in wheat flour, fermentation is employed to get rid of this substance.

4076. It was discovered by Leeuwenhoeck, with the aid of a microscope, in 1716, that starch consists of globular grains, each enveloped in a tegument, pocket, or sac, differing from the internal mass. In 1825, these observations were confirmed and extended by Raspail, who also

\* Graham, page 757.

observed that the envelope, or tegument, was insoluble in water, while the interior portion was soluble in this liquid. Agreeably to the microscopic observations of this last mentioned author, the sizes of the globules of fecula vary with the plant whence it may be derived. Those of the potato did not exceed in diameter  $\frac{1}{16}$  of an inch; those of wheat  $\frac{1}{16}$  of an inch; and of arrow-root  $\frac{1}{16}$ . As, according to Payen and Persoz, the tegument does not form more than four or five thousandths of the weight, the internal portion may be considered as characterizing the whole, uninfluenced to any important extent by the tegumentary matter.

4077. Fecula is blackened by a certain quantity of iodine, becomes blue with less, and violet with still less. The iodide of starch becomes colourless at a temperature less than  $200^{\circ}$ , and if not made to reach the boiling point, regains its colour on cooling.

4078. Starch does not combine with cold water, but forms a viscid solution with hot water. It is neither dissolved nor acted upon by alcohol or ether.

4079. Fecula dissolves in nitric acid without heat, and when heated with it is converted into oxalic acid. A slight torrefaction changes its nature, so that it may be used as a substitute for gum. Triturated with potash, fecula acquires the property of dissolving in cold water. The solution is clouded by acids.

4080. Its solution in hot water is precipitated by subsalts of lead, and in cold water by an infusion of galls.

#### OF DIASTASE,

#### *And of the Conversion of Fecula into Dextrine and Grape Sugar.*

4081. Boiled in water, constantly replenished for nearly forty hours, with between  $\frac{1}{16}$  and  $\frac{1}{16}$  of its weight of sulphuric acid, fecula is converted into grape sugar. A similar change is alleged to have ensued partially in starch, which was made into a paste with twelve times its weight of boiling water, and kept for two years. By the addition of the glutinous matter obtained by washing wheat dough, and the application of a heat between  $122^{\circ}$  and  $167^{\circ}$  Fah., a similar result is said to have been attained in about ten or twelve hours.

4082. It is well known to those who are acquainted with the manufacture of whiskey from grain, that a portion of malt is necessary to render the wash or wort susceptible of the vinous fermentation; and that the product is much affected by the circumstances under which the infusion of the grain is accomplished. Nearly thirty years ago, my late friend, Col. Anderson, who had distinguished himself by his ingenuity and sagacity in improving the processes and apparatus of our American distilleries, expressed to me an opinion, that the mixture of farina and water became sweeter towards the close of the process of infusion, and that he believed a chemical change was induced, by which more or less sugar was generated. The inference of our ingenious countryman has been fully justified by the researches of Payen and Persoz, whence it appears that, by digestion with malt, fecula is at first partially changed into a sweetish gummy matter, called dextrine, and that this matter is afterwards converted into grape sugar. *Dextrine* has received its name from a peculiar influence which it exercises upon the plane of polarization, during the passage of light.\* It may be considered as holding, as respects its properties, an intermediate position between fecula and grape sugar.

4083. The sugar-producing property thus existing in malt, has been traced to a peculiar principle called *diastase*, which exists therein in a proportion not exceeding a five-hundredth. It is obtained by moistening ground malt with half its weight of water, and exposing the mass to pressure. The exuding liquor is mingled with a quantity of alcohol of 840°, by which the diastase is thrown down impure. By three successive solutions in water, and precipitations by the same means, with subsequent exposure on a glass pane, in thin layers, to a current of air about

\* When light, polarized by reflection from the surface of a plate of black glass, or from the surface of a pile of superposed plates of transparent glass, reaches the eye through a disc of tourmalin, a solution of dextrin being interposed in a tube between the reflecting plate and tourmalin, the light does not disappear in those positions of the tourmalin in which light would be completely absorbed without the interposition of the solution of dextrine; but prismatic colours are produced which follow a certain order, if the plane of polarization is turned from left to right. It is by the order of these colours, that a liquid is said to polarize light to the right or to the left. The solution of starch polarizes to the right, and that of dextrine considerably more so in the same direction; while a solution of cane sugar produces the succession of colours in an inverse order, and is said therefore to polarize to the left. The progress of chemical changes may thus often be observed in a solution of starch, the juices of plants, and other organic fluids.—Graham, 743.



° Fah., pure and dry diastase is obtained in the state of a white amorphous solid matter. Diastase does not combine with gum, sugar, gluten, nor albumen, nor the teguments of the starch, but operates surprisingly, as above described, on starch alone. This change is effected without any absorption of the air, or any evolution of gaseous matter. It takes place either in pleno or vacuo. An infusion of 1 part of starch in 39 parts of water, at about 90° Fah., being mixed with 6.13 parts of diastase, dissolved in 40 parts of cold water, and digested afterwards for an hour, at a temperature between 90° and 100°, gave 86.91 parts of sugar. At the temperature of 158°, one part of diastase will convert 2000 parts of starch into sugar.\*

1084. When sulphuric acid is employed in lieu of diastase, if, by confinement, the temperature and pressure are increased (192), less sulphuric acid will suffice. Less time is requisite when care is taken to prevent too rapid refrigeration.

1085. If a paste, made by subjecting starch and water to ebullition, be gently poured into a boiling dilute solution of sulphuric acid, the pasty consistency soon disappears. In like manner, starch paste loses its gelatinous character when mingled with malt wort, and if kept at a temperature between 190° and 200°, becomes, at the end of some hours, converted into grape sugar.

1086. In proportion as the diastase saccharifies the starch, it disappears itself; and when the solution no longer acts on a fresh portion of starch, the presence of diastase cannot be detected in it. The reaction is probably chemico-electric, and if understood, would throw light on a multitude of phenomena.

1087. When dried, diastase is a white, solid, amorphous substance, soluble in water and in weak alcohol, but insoluble in absolute alcohol. It is not known to enter into combination with any substance.† It received its name from *διαστημι*, I separate, in reference to separation of the envelope of the starch globules (4065).

### *Lignin.*

1088. The tasteless, inodorous, insoluble, but tenacious residues of wood, hemp, cotton, or flax, and other plants,

\* Graham, 745. *Annales de Chimie et de Physique*, Vol. 53, p. 73.

† Gregory's Turner, 943. Graham, 744.

have been deemed to consist of a peculiar vegetable substance, called lignin, from *lignum*, the latin for wood. The formula of lignin, dried between  $300^{\circ}$  and  $350^{\circ}$ , is  $C^{12}H^8O^2$  (Prout).

4089. Graham alleges, that it constitutes about 95 per cent. of baked wood, and that it may be obtained in purity by treating the sawings of wood, paper, or the fibre of lint, cotton, hemp, &c., successively with ether, alcohol, water, diluted acid, and a caustic alkaline solution, so as to dissolve and remove all the matter soluble in those menstrua. Wood consists of an association of capillary tubes, in which, after it is desiccated, agreeably to the observations of Hartig, a quantity of starch remains, in spherical grains of a grey colour. Hence by triturating it, in the state of fine saw-dust, with water, from one-fourth to one-fifth of its weight of starch may be obtained.

4090. If Payen is to be credited, wood consists of two organic principles, one of which is isomeric with starch, having the same formula,  $C^{12}H^{10}O^{10}$ , being named cellulose by him. The other principle, which forms the tubes, is considered by the same author as the true lignin. Cellulose was obtained by subjecting sawings of beech wood to several times its weight of the most concentrated nitric acid, which leaves that principle, while it dissolves the lignin. Cellulose is dissolved by concentrated sulphuric acid without blackening, and is then converted into dextrine. The formula of lint, hemp, straw, and linen cloth, was found by Payen to be  $C^{35}H^{24}O^{20}$ . Oak wood, by the analysis of Gay-Lussac and Thenard, is  $C^{36}H^{22}O^{22}$ .

4091. When hemp, straw, &c., are added cautiously to concentrated sulphuric acid, so as to prevent elevation of temperature, not only is dextrine created, but also ligno-sulphuric acid, analogous to benzo-sulphuric acid, which forms a soluble salt with baryta, or with oxide of lead.

4092. The dextrine formed when lignin is dissolved in sulphuric acid, is converted, by dilution and boiling, into starch sugar.

4093. Saw-dust, gum, and starch, dissolve in the most highly concentrated nitric acid, without decomposing the acid; and, if immediately diluted with water, give a white pulverulent neutral substance, insoluble in water, which contains the elements of nitric acid, and is highly combustible.

34. To obtain grape sugar from lignin, twelve parts reds of paper or linen, or of wood shavings, are intily incorporated by trituration with seventeen parts ncentrated sulphuric acid (according to Vogel five ), and one of water, carefully preventing any rise of erature. After twenty-four hours, the resulting tarry is to be dissolved in water, boiled for ten hours, neu- ed with chalk, and being filtered and evaporated to a y consistence, the residue is to be left to crystallize.

35. According to Brunner, 100 parts of fecula yield f crystallized grape sugar; according to De Saussure,

Agreeably to calculation, 100 of fecula, with four of water, should be productive of 120 of sugar. 100 of linen shreds produce 114 of sugar, according to onot; or, according to Guerin, 115 parts.

36. It is worthy of remark, that the formula of crys- d grape sugar may be made by adding to the for- of lignin six atoms of water; to that of starch, four ; to that of cane sugar, three atoms; and to that of of milk, two atoms.

a of lignin,	$C^{13} H^8 O^8$	Starch,	$C^{13} H^{10} O^{10}$
ms of water,	$H^6 O^6$	Four atoms of water,	$H^4 O^4$
lized grape sugar,	$C^{13} H^{14} O^{14}$	Grape sugar,	$C^{13} H^{14} O^{14}$
lized cane sugar,	$C^{13} H^{11} O^{11}$	Sugar of milk,	$C^{13} H^{13} O^{13}$
atoms of water,	$H^3 O^3$	Two atoms of water,	$H^2 O^2$
sugar,	$C^{13} H^{14} O^{14}$	Grape sugar,	$C^{14} H^{14} O^{14}$

## OF VEGETO-ANIMAL SUBSTANCES.

· this *Head are included Gluten, Vegetable Albumen, getable Fibrin, and Legumen, or Vegetable Caseine.*

37. Plants contain substances which have been desig- as vegeto-animal, on account of their analogy with bite of egg, and the fibrin of animal matter. Nitro- always an ultimate element in them, and occasion- ulphur and phosphorus. As they are to be found in getables, to a greater or less extent, it appears pro- arrange them under the head of the general princi- f vegetables.

38. It had long been known that wheat dough, by enclosed and kneaded within a porous bag, while

subjected to water, might be resolved into a portion which would be washed away by the water, and an adhesive portion left within the bag.

4099. Beccaria first drew the attention of chemists to the substance thus obtained. Subsequently, Rouelle, Jr., demonstrated the existence in the expressed juices of many plants, of a substance coagulable by heat, like animal albumen. This coagulable matter was, by Fourcroy, deemed to be of the same nature as the albumen of eggs. Subsequently, Einhof demonstrated the existence, in rye, barley, peas, and beans, of two vegeto-animal substances; one resembling white of egg, the other, which he designated as gluten, was not considered as resembling any animal substance.

5000. It may be inferred, from the account of gluten given by Berzelius, that both Einhof and Taddei subjected the gluten of Beccaria to boiling alcohol, and thus resolved it into two substances; one similar to albumen in its properties, the other soluble in alcohol, especially when boiling, and possessing, in a high degree, the adhesiveness and other properties by which gluten had been distinguished.

5001. The matter taken up by the boiling alcohol was, by Taddei, designated as gliadine, from *γλιν*, glue, the portion remaining undissolved, zimome, from *ζυμος*, leaven. Berzelius treats the matter, soluble in alcohol, as gluten nearly pure, and the residue as vegetable albumen, and gives the following account of the sources and properties of gluten and the vegetable albumen with which it is associated.

### *Gluten.*

5002. It owes its name to the adhesive property which it possesses, and which it communicates to wheat dough. It exists in the seed of the grape, and of the cerealia especially; also in those of leguminous plants, such as peas and beans, in which it is found in combination with starch and vegetable albumen. Its distinguishing characteristics are as follows. When isolated, it is almost insoluble in water. It is gluey when moist, yellow and translucent when dry. Ordinarily, it has an acid reaction with litmus, in consequence of the presence of acetic and phosphoric acid. It is soluble in alcohol, especially when boiling, and likewise in diluted aqueous solutions of acids, caustic alk-

eyes, &c. It is precipitated from the latter by ferro-prussiate of potash. With nut-galls it gives a precipitate, which is not redissolved even by ebullition.

### *Vegetable Albumen.*

03. It is found in the above mentioned seeds in combination with gluten; in seeds which yield emulsions, as, for instance, in almonds; and likewise in the seeds of the cereals, where it is found in combination with an oil. It is found in all vegetable juices which coagulate with heat. Vegetable albumen is soluble in water, until coagulated by heat, but is not soluble in alcohol; it is not adhesive, and on desiccation becomes opaque, and of either a white, yellow, brown, or black colour. It dissolves readily in dilute alkaline solutions, neutralizing their caustic taste, and is precipitated by a great excess of acid. The precipitate is a chemical compound of albumen with the acid, soluble in water when pure, but less so when this liquid is diluted.

04. The aqueous solution of vegetable albumen is precipitated by acids, by ferro-prussiate of potash, by chlorure of mercury, and infusion of galls; being, in these respects, perfectly analogous to animal albumen.

05. Gluten and vegetable albumen spontaneously undergo decomposition, accompanied by an evolution of ammonia, a production of the acetate of ammonia, and like the fetor which distinguishes the putrefaction of animal substances. At a certain period of putrefaction, they, whether separate or mixed, the smell of old cheese.

### *Of the Gluten and Albumen of Wheat.*

06. If we make a thick paste of wheat with water, in a porous bag, and knead this paste within the bag, under pressure, until this liquid is no longer rendered milky, there remains, finally, a gray coherent elastic residue. This residue consists mainly of a mixture of gluten and vegetable albumen, not quite free from other matter derived from wheat, and more or less of starch, which it is difficult to remove completely. This residue does not contain the whole of the vegeto-animal matter of the wheat, a part being carried away by the water during the kneading of the paste.

5007. To separate from each other the albumen and gluten proper, contained in the gluten of Beccaria, it is necessary to subject it to boiling alcohol, till this liquid, on being filtered, is not made turbid by cooling. The alcohol dissolves the gluten proper, as well as another substance imperfectly known, leaving the vegetable albumen. The gluten is obtained by mixing the alcoholic solution with the water, and removing the alcohol by distillation. A liquid remains, in which the gluten floats in coherent voluminous flocks. A very small portion of gluten remains in solution, combined with gum.

5008. The gluten being separated from the liquid, is of a pale yellow, and readily becomes agglutinated into a mass, which sticks to the fingers, is elastic, insipid, and endowed with a peculiar odour. In dry air it becomes spontaneously polished on the outside, and of a deeper yellow, drying, by little and little, into a translucent mass of a very deep yellow, resembling dried animal matter. Alcohol dissolves the gluten, and the solution, which is of a pale yellow, being evaporated, the gluten remains in the form of a yellow transparent varnish. If the gluten be macerated in cold alcohol, it is whitened, and forms a milky solution, from which an insoluble matter is deposited. This is not gluten, though of a kindred nature, being soluble by the aid of ebullition; the resulting solution, when concentrated, acquires a mucilaginous consistence on cooling. Gluten dissolves in boiling officinal alcohol, and precipitates by refrigeration, without having lost its gluey quality. It is insoluble in ether, or in fixed oils or volatile oils. If we subject it to acetic acid, it becomes, in consistency, mucilaginous, semi-liquid, losing its yellow colour. Mixed in this state with water, it gives a mucilaginous flocky residuum and a milky solution.

5009. From the investigations of Einhof, as stated by Berzelius, it appears that a matter, analogous to that above described as true gluten, may be obtained from rye, barley, oats, or even from maize, which, from the absence of any cohesiveness in its moistened meal, would not be supposed to contain any matter deserving to be distinguished as gluten.

5010. It will be perceived, from the preceding history of the opinions and observations of chemists, respecting the vegeto-animal matter obtained from wheat and the seeds

other vegetables, that the idea lately put forth by Liebig, respecting the identity of their composition with animal albumen, has long been entertained, though never before presented so forcibly to popular attention.

§11. Respecting the matter treated as gluten by Berzelius, Liebig advances views which are in some respects correct, and somewhat discordant. I will here quote the language of the author last mentioned:—

These nitrogenized forms of nutriment in the vegetable kingdom may be reduced to three substances, which are easily distinguished by their external characters. Two of them are soluble in water, the third is insoluble.

When the newly-expressed juices of vegetables are allowed to stand, a separation takes place in a few minutes. A gelatinous precipitate, commonly of a green colour, is deposited, and this, when acted on by liquids which remove the colouring matter, leaves a grayish white substance, well known to druggists as the deposit of vegetable juices. This is one of the nitrogenized compounds which serves for the nutrition of animals, and has been named *vegetable fibrin*. The juice of grapes is especially rich in this constituent, but it is most abundant in the seeds of wheat, and of the cerealia generally. It may be obtained from wheat flour by a mechanical process, and in a state of tolerable purity; it is then called *gluten*, but the gluten property belongs, not to vegetable fibrin, but to a foreign substance present in small quantity, which is not found in the other cerealia.

The method by which it is obtained, sufficiently proves that it is insoluble in water; although we cannot doubt that it was originally dissolved in the vegetable juice, from which it afterwards separated, exactly as fibrin does from blood.

The second nitrogenized compound remains dissolved in the juice after the separation of the fibrin. It does not separate from the juice at the ordinary temperature, but is instantly coagulated, when the liquid containing it is heated to the boiling point.

When the clarified juice of nutritious vegetables, such as cauliflower, asparagus, carrot, or turnips, is made to boil, a coagulum is formed, which it is absolutely impossible to distinguish from the substance which separates as coagulum from the serum of blood or the white of an egg, diluted with water, are heated to the boiling point. This is *vegetable albumen*. It is found in the greatest abundance in certain seeds, in nuts, almonds, and others, in which the starch of the gramineae is replaced by oil.

The third nitrogenized constituent of the vegetable food of animals is *vegetable caseine*. It is chiefly found in the seeds of peas, beans, lentils, and similar leguminous seeds. Like vegetable albumen, it is soluble in water, but differs from it in that its solution is not coagulated by heat. When the solution is heated or evaporated, a skin forms on its surface, and the addition of an acid causes a coagulum, just as in animal milk.

These three nitrogenized compounds, vegetable fibrin, albumen, and caseine, are true nitrogenized constituents of the food of graminivorous animals; all other nitrogenized compounds, occurring in plants, are either rejected by animals, as in the case of the characteristic principles of poisonous and medicinal plants, or else they enter in the food in such very small proportion, that they cannot possibly contribute to an increase of mass in the animal body.

The chemical analysis of these three substances has led to the very interesting result that they contain the same organic elements, united in the same proportion by weight; and, what is still more remarkable, that they are identical in composition with the chief constituents of blood, animal fibrin, and albumen. They all three dissolve in concentrated muriatic acid with the same deep purple colour; and even their physical characters, animal fibrin and albumen are in no respect different from vegetable fibrin and albumen. It is especially to be noticed, that by the phraseology of composition, we do not here imply mere similarity, but that even in relation to the presence and relative amount of sulphur, phosphorus, and phosphate of lime, no difference can be observed."

§12. In addition to the information conveyed in the preceding quotation, we are informed in a note (8) that

the portion of wheat flour, above alluded to, under the name of fibrin, is that which is not taken up by boiling alcohol from the glutinous mass mechanically obtained by washing wheat dough in a bag.

5013. The vegetable fibrin of Liebig is, therefore, the vegetable albumen of Einhof and Berzelius, or the zimome of Taddei.

5014. The statement in the note, that "*pure gluten is the portion of raw wheat flour which is soluble in hot alcohol*," is not consistent with the allegation, that the glutinous quality is due to a foreign substance present in small quantity, and which is not found in other cerealia. This allegation is, moreover, inconsistent with the observations of Einhof, as stated by Berzelius, that gluten is found in rye, barley, and in small proportion in maize. Besides, it is difficult to believe that the adhesiveness of wheat dough, to which it owes its power of confining the carbonic acid generated during panification, can be the effect of a *small quantity of foreign matter*. It would seem to require a quantity of matter intimately associated with the farina, and pervading the whole of the dough, into which it is converted in the bread making process.

5015. There seems, however, to be good grounds to suppose the existence of an error in estimating the nourishing power of different kinds of grain, to be in proportion to the quantity of glutinous matter obtained from them by washing, since the farina of maize, which for equal weight is in this country considered at least as nutritive as wheat, seems to have not perceptible adhesiveness. Hence, the statement of Liebig, however inconsistent with preconceived opinions, may point towards an important truth, that there is a vegetable fibrin meriting the highest rank as animal food, which differs from pure gluten in not being soluble in alcohol nor glutinous; and from vegetable albumen, in not being soluble in water, nor coagulable by heat.

5016. The idea, above quoted from Berzelius, respecting the superiority of wheat as a nutriment, being due to its holding a peculiarly large proportion of gluten, has generally prevailed; and by Sir H. Davy the opinion was entertained, that the wheat of more southern climates was, on account of a greater abundance of gluten, more nutritious than grain of the same kind, raised in colder latitudes. To a greater abundance of the same matter, has



been ascribed the superior capability in wheat dough of what is called *rising*; as the gluten, by preventing the escape of carbonic acid, causes the inflation of innumerable little cavities producing the cellular structure which distinguishes leavened bread.

5017. It appears, that during panification there is actually a generation of alcohol, as well as carbonic acid, so that in the usual process there is an incipient fermentation.

5018. Gingerbread, however, owes its lightness to a different process. Being made of flour and molasses, with a suitable addition of an alkaline carbonate, an acid is gradually generated by the absorption of atmospheric oxygen, which displaces the carbonic acid from the carbonate, (1198.) The gas, thus liberated from the alkali, being confined by the gluten, when the bread is placed in an oven, an inflation of every part arises from the expansion of the gaseous matter.

5019. A bicarbonate is more efficacious than pearlash in causing gingerbread to rise, as in proportion to the alkali it yields double the quantity of gas. A bicarbonated alkali is found to act as a leaven for cakes, when old cider is mingled with the dough. Tartaric acid has been used for this purpose, and lime juice might be employed, or any well flavoured vegetable acid. An equivalent portion of chlorohydric acid might be resorted to.

5020. It is supposed that bakers generally use a sufficiency of pearlash to neutralize the acidity which is liable to supervene in their yeast or leaven; and that latterly, carbonate of soda having become cheaper, has been preferred. An erroneous prejudice has existed as respects this practice, whereas evidently sourness in bread must be more injurious to health than an alkaline acetate.

5021. Carbonate of ammonia has been used, and is alleged, by being vapourized during the baking process, to contribute to the inflation and consequent sponginess of the bread in which it is used.

5022. More than forty years since, a candidate for graduation in our university, Dr. Pennington, published a thesis, in which bread was described as being simultaneously salted and raised, by the addition to the dough of chlorohydric acid and carbonate of soda, in due proportion. Rolls are alleged to be rendered lighter, when made with carbonated water, of the Congress spring at Saratoga. The knowledge which we now have of the equivalent proportions in which to use bases and acids, renders experiments of this kind much more easy than they were at the period when Dr. Pennington graduated. Of course a bicarbonated alkali should in all cases be preferred, for the reason above given.

*Legumen, or Vegetable Caseine.*

5023. The substance bearing these names, appears to be intermediate between gluten and vegetable albumen, not being coagulable by heat like the one, nor like the other soluble in alcohol while insoluble in water. It is, however, alleged by Liebig, that agreeably to recent analyses made in his laboratory, there is no difference as respects composition, between gluten, vegetable albumen, vegetable fibrin, and vegetable caseine, nor between these substances and those of the same names derived from animals.

*Composition of Vegetable Fibrin, Vegetable Albumen, Vegetable Caseine, and Vegetable Gluten.*

	VEGETABLE FIBRIN.				Gluten, as obtained from wheat flour.	
	Scherer.* a			Jones.* b	Marcat. c	Boussingault.
	I.	II.	III.	IV.	I.	II.
Carbon	53.064	54.603	54.617	53.83	55.7	53.5
Hydrogen	7.132	7.302	7.491	7.02	14.5	15.0
Nitrogen	15.359	15.809	15.809	15.58	7.8	7.9
Oxygen	}	22.255	22.083	23.56	22.0	24.5
Sulphur						
Phosphorus						

a Ann. der Chem. und Pharm. XL. 7.

c L. Gmelin's Theor. Chemie, II. 1092.

b Ibid. XL. 65.

	VEGETABLE ALBUMEN. a				
	From Rye.	Wheat.	Gluten.	Almonds.	
	Jones.*	Jones.*	Varrentrapp & Will.*	Jones.*	
Carbon	54.74	55.01	54.85	57.03	
Hydrogen	7.77	7.23	6.98	7.53	
Nitrogen	15.85	15.92	15.88	13.48	
Oxygen	}	21.64	22.39	21.96	
Sulphur					
Phosphorus					
		Boussingault.	Varrentrapp and Will.*		
Carbon	-	52.7	—		
Hydrogen	-	6.9	—		
Nitrogen	-	18.4	15.70		
Oxygen, &c.	-	22.0	—		

a Ann. der Chem. und Pharm. XL. 66, and XXXIX. 291.

	VEGETABLE CASEINE. a			
	Scherer.*	Jones.*	Sulphate of Caseine and Potash.	
			Varrentrapp and Will.	
Carbon	54.138	55.05	51.41	51.24
Hydrogen	7.156	7.59	7.83	6.77
Nitrogen	15.672	15.89	14.48	13.23
Oxygen, &c.	23.034	21.47	—	—

a Ann. der Chem. und Pharm. XXXIX. 291, and XL. 8 and 67.

## VEGETABLE GLUTEN.

Jones.* a			Boussingault.	
Carbon	-	55.22	54.2	52.3
Hydrogen	-	7.42	7.5	6.5
Nitrogen	-	15.98	13.9	18.9
Oxygen, &c.	-	21.38	24.4	22.3

a Ann. der Chem. und Pharm. XL. 66.

the gluten, analyzed by Jones, was that portion of the raw gluten from which is soluble in hot alcohol. The insoluble portion is vegetable fibrin, some of which has been already given.

## Composition of Animal Caseins. a

Scherer.				
From fresh milk.	From sour milk.		From milk by acetic acid.	Albuminous substance in milk. b
I.	II.	III.	IV.	V.
54.825	54.721	54.665	54.580	54.507
7.153	7.239	7.465	7.352	6.913
15.628	15.724	15.724	15.696	15.670
22.394	22.316	22.146	22.372	22.910

der Chem. und Pharm. XL. 40 et seq.  
substance, called, in German, *zieger*, is contained in the whey of milk coagulated by an acid. It is coagulated by heat, and very much resembles

Malder. a				
Carbon	-	-	-	54.96
Hydrogen	-	-	-	7.15
Nitrogen	-	-	-	15.89
Oxygen	-	-	-	21.73
Sulphur	-	-	-	0.36

a For the analysis of vegetable caseins, see the preceding page.

## Of Vegetable Colouring Matter, or Dyes, and of Dyeing.

None of the operations of nature are more inscrutable, than those by which organic substances are endowed with the immense variety of colour with which vegetables and animals are adorned. The chemist knows how to elaborate dyes, to fix them, and in fixing them, by the use of mordants, to vary their hues; but excepting the influence of different media, or of crystalline structure, in dispersing refracted or polarized rays, he is still quite ignorant of the differences in the arrangement of molecules which give rise to diversity of colour; or of the mode in which a particular combination causes the various colours of precipitates.

Colouring substances or dyes are divided into substantive and adjective dyes. The former, with little disposition to dissolve in water, have an affinity for the fibre to be dyed, and enter directly into union therewith. The adjective colours, having little or no affinity for the fibre to be dyed, are to be attached, an union is produced by an intermediate substance having an affinity for both, and which is consequently called a mordant, *mordant*, biting, in French. In some cases the colour is changed by the mordant, in others improved and heightened.

Lakes are precipitates of colouring matters, made by the substance used as mordants. By presenting them, in a proper state of combination, to colouring matter, both alumina and oxidized iron are used exclusively.

tensively as mordants, and for the formation of lakes. By means of cochineal dye and protoxide of tin, the well known scarlet of the military uniform of Great Britain is produced. The ordinary carmine of commerce, is a lake produced from that dye by alumina. Chinese carmine is produced by the same dye with protoxide of tin.

5027. Indigo is a substantive dye which is made to attach itself to woollen cloth, without the aid of a mordant. By digestion with lime and green sulphate of iron, it is rendered white. When in this state it unites with the woollen fibre, and by subsequent exposure to air, regains its blue colour. The rationale of this process, suggested by Liebig, is as follows:—

5028. A soluble colourless substance, which may be called indigogene being generated in the indigo plant, is by oxidizement converted into the insoluble blue indigo of commerce. In the process of dyeing, the oxide of indigogene or blue indigo is deoxidized by protoxide of iron, liberated by the lime from the sulphate, and is thus restored to its whiteness and solubility. In this state, combining with the organic fibre, it is subsequently reconverted into insoluble blue indigo by union with atmospheric oxygen.

5029. But Kane conceives, that Dumas has proved by analysis, that *soluble white* indigo is a hydruet of *insoluble blue* indigo. Each atom of the hydruet being deprived of an atom of hydrogen, during the macerating process of the manufacturer, the indigo loses its solubility and assumes its appropriate blue colour. In this state it is found in commerce, and when subjected to the process of the dyer, above alluded to, is made to receive an atom of hydrogen liberated by an atom of water, of which the oxygen is simultaneously seized by the protoxide of iron. The hydruet thus formed combining with the organic fibre, while colourless and soluble, by subsequent exposure to air is dehydrogenated, and thus again converted into an insoluble blue dye.

5030. Indigo is soluble in concentrated sulphuric acid, especially the fuming acid of Nordausen. The solution thus made, yields what is called the Saxon blue. Previously to the immersion of the cloth, the solution is neutralized by carbonate of soda, which uniting with the acid, the dye attaches itself to the organic fibre, whether it be wool, silk, or cotton.

5031. Indigo forms various peculiar combinations, to which it would be inexpedient to direct the attention of those who study chemistry only as auxiliary to medicine.

#### *Of the Colouring Matter of Leaves and Flowers.*

5032. The green colour of plants is said to be due to the pressure of a substance called chlorophyll. This has not been obtained sufficiently pure to have any formula assigned to it. It does not contain nitrogen, is insoluble in water, but soluble both in ether and alcohol, and in strong acids. From these, however, it precipitates on dilution. It combines with bases.

5033. Berzelius conceives three kinds of chlorophyll to exist. The first, existing in fresh leaves, dissolves in acetic acid with a rich grass-green colour; the second, formed from the first by drying, gives with the same acid an indigo blue solution; the third, which exists principally in the dark leaved plants, is brownish green.

5034. So potent is the colouring power of chlorophyll, that Berzelius has calculated that all the foliage of a large tree seldom contains ten grains of it. When trees change colour in the fall, chlorophyll is, according to the same chemist, replaced by other colouring matter.

5035. Chlorophyll floats in the cells, existing in the green leaves of plants in general, in the form of green globules, from which it may be extracted by ether. The ethereal solution thus obtained, being subjected to the distillatory process to remove the solvent, the residue is digested in alcohol, which takes up impure chlorophyll. The alcohol, being entirely removed, the residual matter is subjected to concentrated chlorohydric acid, by which a fine emerald green colouring matter is dissolved. This precipitating on dilution, is digested in a strong lixivium of potash. The resulting compound being dissolved by water, the solution, after being filtered, is saturated with acetic acid, when beautiful green flocks precipitate of pure chlorophyll, which in drying become bluish green. Graham, 907.

### *Of Oils.*

5036. When not figuratively used to describe substances having only an oleaginous consistency, like oil of vitriol, the word oil has been applied to two classes of substances, differing in most respects in their properties and chemical constitution. One of these classes has been called fixed, from their insusceptibility of being distilled without decomposition. But as margaric acid, a principal constituent in a majority of fixed oils, and spermaceti, a concrete animal oil, may be distilled without change, this definition is not universally consistent. It would, therefore, be preferable to designate as fixed oils those which do not spontaneously evaporate when exposed to the air, or which are not vaporized at the boiling point of water, when subjected to the distillatory process with that liquid.\*

### *Of Fixed Oils.*

5037. I propose rather to treat briefly of the general properties of fixed oils, of their composition, and of the theory of their conversion into soap, than to give an account of each of them particularly.

5038. There is no essential difference between *fat*, and oil. The one differs from the other, merely, in a greater

\* By distinguished writers, such oils have been designated as *fat* or *unctuous* oils. But as *unctuous* and *oily* are synonymous words, and as *fats* are concrete oils, the use of the words in question, in the way alluded to, were equivalent to saying *oily oils*, or *fat fats*. The word *greasy* though inelegant, would be more appropriate, similarly applied, than *unctuous*, as one of the most characteristic differences between volatile and fixed oils is the presence of this property in the one, and its absence from the other.

Kane distinguishes fixed oils as *saponifiable*. But as chemists consider compounds of certain oily acids with bases as soaps, evidently (4032) fixed oils are native compounds meriting this appellation; as will shortly be made more evident. It is the oily acid ingredient, not the compound formed with it, which can be saponified. I should conceive it, therefore, more proper to designate the oils in question, as *soap oils*, or *unctuous soaps*.

propensity to the fluid state. That which may pass for fat in winter, may become oil in summer. The oils of animals are generally in the solid state of fat; those of vegetables are generally liquid.

5039. Although fats and oils, as they exist in nature, appear to be homogeneous, they all consist of two or more oleaginous substances, of which one is more fluid than the rest. The more fluid ingredient, named olein, is found in its chemical habitudes and composition to be the same in a great majority of instances, but the less fluid portion consists very extensively of a matter called stearine, more or less associated with another, rather more fusible and much more soluble in alcohol and ether, called margarine. Indeed, this last mentioned substance abounds in human fat, and in that of some other animals, and in vegetable oils predominates. Besides margarine and stearine, the following analogous substances have been noticed in various kinds of fat, or oily matter; as for instance, spermaceti in the cachalot whales; delphinine in the oil of the dolphin and common whale; butyrin, caproin and caprin in butter; myristicine in butter of nutmegs; ricino stearine, ricino olein, and ricin, in *ricinus communis*; crotonine in the oil of *crotontiglium*; cocostearine in cocoa nut oil; palmatine in palm oil.\*

5040. Spermaceti is obtained, as is well known, from the crania of cachalot whales, whence its inappropriate name, from sperma, seed, and cetus, a whale. The part allotted to it, is analogous to that which stearine performs in tallow or suet; but that it differs in composition has been already mentioned, and to keep it in fusion requires a temperature peculiarly high. Hence it crystallizes from its solvent olein, at the ordinary temperature of the air.

5041. The *summer strained* and *winter strained* oils of commerce, severally consist, the one of a large portion of olein, with a small proportion of stearine, the other of the same materials, but with a greater proportion of the more solid constituent. The appellation given to these oils, conveys the idea of the fact, that the one is obtained by

\* Mr. Stenhouse having isolated the stearine of palm oil, alleges its formula to be as follows,  $C^{33}H^{66}O^4$ ; and that it consists of one atom of a peculiar fat acid, which he calls the palmatic,  $C^{32}H^{62} + O^3$ , and one atom of oxide of glyceryl. He assigns, however, a new formula for the latter,  $C^3H^4O^1$ , which Berzelius does not consider as admissible upon the evidence of this author alone, while inconsistent with the previous analysis made by Liebig and Pelouze.



5048. Its composition will appear from the following formula of its ingredients :—

One atom oxide of glyceryl,	-	-	$C^6 H^7 O^3$
Two „ margarinic acid,	-	-	$C^{68} H^{66} O^8$
One „ water,	-	-	$H O$
Formula of margarine,			$C^{74} H^{71} O^{12}$

5049. *Olein*.—In concrete oils, usually called fats, olein exists in but a small proportion, but constitutes a large portion of all the fixed oils which are not drying, or, in other words, capable of hardening by exposure to the air. As found in nature, it always holds more or less stearine and margarine. Margarine abounds in olive oil. In the oil obtained from sweet almonds by expression, there is less margarine in proportion to the olein than in any other. In this respect rape seed oil approximates most nearly to the oil of sweet almonds.

5050. Olein is best obtained by dissolving almond oil in ether heated nearly to its boiling point, and afterwards cooled till the margarine congeals, so as to be separated by straining. Olein, thus obtained, remains liquid at zero, F.

5051. The composition of olein is inferred to be as follows :—

One atom of glyceryl,	-	-	$C^6 H^7 O^3$
Two „ oleic acid,	-	-	$C^{68} H^{72} O^8$
Two „ water,	-	-	$H^2 O^2$
Hence the formula of olein is	-	-	$C^{94} H^{97} O^{13}$

### *Of Saponification.*

5052. In treating of glyceryl and cetyl (4029, 4036), it has been explained, that all fixed oils, whether concrete or liquid, are supposed to be compounded of two ingredients, one acting as a base, the other as an acid, and that in a great majority of cases an oxide of glyceryl is inferred to be the base. Hence, when substances in which it exists in this capacity are boiled with an alkaline oxide, the oxide of glyceryl is dispossessed of its acid. The acids thus trans-



red to the alkaline oxide have been named from the substances by which they are respectively yielded.

thus Stearine gives		Stearic acid.
Margarine		Margaric acid.
Olein		Oleic acid.
Butyrin	}	Butyric acid.
Caproin		Caproic acid.
Caprin		Capric acid.
Delphinine		Delphinic acid.
Myristicine of Nutmeg Butter		Myristicic acid.
Ricino Stearine	}	Ricino Stearic acid.
Ricino Olein		Ricino Oleic acid.
Ricin		Ricinic acid.
Crotonine, Oil of Croton Tiglium		Crotonic acid.
Cocoa Stearine		Cocoa Stearic acid.

5053. It remains doubtful whether the acids thus elaborated exist ready formed, in union with the oxide of glyceryl, or whether both base and acid are generated during the process of saponification. The former opinion, however, is supported by the fact, that, by the direct union of stearic acid with the oxide of ethyl, an oil is formed, which, on being cooled below  $90^{\circ}$ , solidifies with all the appearance of a fat. If the artificial fat, consisting thus of ethyl, be boiled with caustic potash, the results of the reaction of that alkali with stearine, under similar circumstances, are exactly reproduced; except that while stearate of potash is formed in both cases, an oxide of ethyl is generated in the latter instead of the oxide of glyceryl. It may, therefore, be presumed, that stearine, olein, &c., may be regarded as definite salts formed by the union of the fat acids, which are respectively produced from them with the oxide of glyceryl.

5054. The oxide of glyceryl is the base of a majority of saponaceous bodies, the difference between them being produced by the diversity of the acids which enter into their composition. In the single case of spermaceti this general rule is reversed, the acids being the same as those which are present in large quantities in the fat of men or of sheep, while the base is the oxide of another radical, cetyl, capable, as already mentioned, of combining with sulphuric acid to form a compound corresponding to sulphovinic acid, and likewise of existing as a hydrate, or in a state analogous to

that of ethyl in alcohol. It would appear, therefore, that while we must regard common tallow, or suet, as a stearate, margarate, and oleate of oxide of glyceryl, spermaceti must be looked upon as a margarate and oleate of oxide of cetyl. It may be observed, that the view of the composition of the different fats here given, and founded on the fact of their decomposition by alkalies into an acid and a base, is confirmed by the result of direct analysis, which, when disposed in a rational formula, in all cases gives the number of atoms necessary to represent the organic acid and base which they are supposed to contain.

5055. In a paper published in the last number of the American Journal of Science, Dr. Smith, as the result of a careful analytical investigation, alleges that ethalic acid is the sole electro-negative product of reaction of spermaceti with alkalies, in the process of saponification; and that the margaric and oleic acids, are not evolved by that process. He supposes that an atom of spermaceti,  $C^{44} H^{64} O^2$ , is separated by the action of potash into an atom of ethalic acid,  $C^{32} H^{31} O^2$ , and one atom of ethal,  $C^{12} H^{33} O$ . From the fact that the ethal, thus separated, by a farther treatment with potash at a high temperature and with access of air, may be completely converted into ethalic acid, Smith infers that the saponification of spermaceti differs from that of ordinary fats, since the glycerine, which they yield, is insusceptible of further acidification: also that spermaceti must be regarded as a homogeneous fatty body, not containing, ready formed, either the acid or base which it affords when treated with alkalies.

#### *Properties of the Fixed Oils.*

5056. I infer that fixed oils, when not accompanied by any other matter, are nearly colourless, insipid, and inodorous. The smell and taste produced by them, in the state in which they come under our observation, is obviously due to some volatile oil or acid with which they are associated. Their colour is evidently caused by foreign matter, as they may be decolorized by charcoal. In some instances impurities exist in them naturally, in others are produced during their elaboration or subsequent exposure to atmospheric oxygen, by which they are more or less oxidized, and brought into the state called rancidity. The fine flavour of fresh grass butter, and the nauseous

savour of that which is rancid, are neither of them to be ascribed to the pure oil of butter, which, when fresh made from cream obtained from cows fed on hay, although sweet, is not highly flavoured.

5057. The difference between cold pressed olive, or castor oil, and that obtained with the aid of heat, shows, that in proportion as substances of this kind are more near to the natural state, the less they are endowed with colour, or any activity as respects taste or smell.

5058. Boiling with magnesia, diminishes the unpleasant smell and taste of rancid oils, by removing the acid which causes those defects.

5059. As in every animal, and in a great number of vegetables, fixed oils are more or less to be found, of which each affects the sight, the smell, and taste, in a different way, it might be imagined that there was much difference in the proportions of the ultimate elements of which they are formed.\*

5060. But it has already been made evident, that, in organic products especially, diversity of properties, is not attended by corresponding diversities in the proportions of ultimate elements. However, in the case of the substances under consideration, it is probable that there would be very little difference in properties to be accounted for, could those substances be obtained free from certain volatile oils and acids by which they are accompanied. It is not, therefore, surprising, that the results of ultimate analysis do not display any material difference as to the ratio in which carbon, hydrogen, and oxygen, enter into their composition.

5061. Agreeably to quotations made by Raspail, of the ultimate analysis, by various distinguished chemists, of twelve species of oils, including white wax, it appears that the differences resulting from the diversity in composition,

\* Mr. M. S. Wright has, by means of ether, extracted from spurred rye or ergot (*secale coruntum*) a fat and saponifiable oil, which has the odour of the ergot, and which he alleges to have a like efficacy. This oil is changed by exposure to air, especially if simultaneously heated, becoming, in consequence, brown. Nevertheless it may be kept unchanged, in well closed vessels. It is soluble in alcohol, ether, sulpho-carbonic acid, and fixed and volatile oils. Berzelius deems it worthy of a more thorough examination. Report for 1841, page 150.

It may be inferred, so far as reliance is to be placed on the statement of Mr. Wright, that the active principle of ergot is associated with the oil abovementioned. No reference is made to the ergotin of Wiggers, supposed by him to be the active principle of ergot. U. S. Dispensatory, 565.

are less than those arising from variation in the manipulations of the different analysts.

5062. There seems, however, to be some justification for the idea, that in concrete oils there is more carbon; and that solubility in alcohol increases with the proportion of oxygen.

5063. The carbon in the less fluid portion of olive oil is to that in the more fluid portion, as  $82\frac{1}{11}$  to  $76\frac{1}{11}$ , while the oxygen of the latter, which is the only part soluble in alcohol, is to the former, as  $12\frac{1}{11}$  to 6.

5064. This inference is supported by the fact, that while the fusing points of spermaceti and beeswax are pre-eminently high, so likewise is their proportion of carbon.

5065. Fixed oils are all more or less liable to a slow union with atmospheric oxygen, by which they are thickened and rendered less fit for combustion in lamps: but some oils are susceptible, in this way, of attaining a degree of induration, forming on the surface an adhesive and elastic pellicle resembling gum elastic. This tendency is increased by boiling the oil from three to six hours with from a half ounce to an ounce of litharge, and one-fourth of an ounce of sulphate of zinc, by which mucus is alleged to be coagulated, which protects the oil from oxidation by atmospheric oxygen.

5066. The oils capable of being thus changed are called drying or siccative oils. Berzelius applies the term "non siccative" to those which are not capable of indurating by exposure. Linseed oil is the most abundant of the drying oils, and hence is most employed in making pigments and varnishes. The oils of hemp seed, of nuts, of the seeds of the ricinus communis, of croton tiglium, of the belladonna of tobacco, of the sunflower, are placed under the siccative head by the same author.

5067. The drying oils are said to consist of the oxide of glyceryl united to a peculiar liquid acid differing from oleic acid.\*

\* Liebig alleges himself to have ascertained that the presence of glyceryl in oil is indispensable to qualify it for a varnish: since neither the olein alone, nor its combination with margaric acid, produces, with oxidized lead, a varnish capable of speedy drying.

The success of the following process, recommended by Mr. Jonas, seems to show that the oxide of lead may be replaced in the usual process by another oxidizing agent. To 100 pounds of oil, heated previously in a copper boiler, add, drop by drop, from two to four "gros" of concentrated nitric acid, agitating the oil continually. The acid is decomposed with a lively effervescence. The oil, after this treatment,

5068. When oils are made to present an extensive surface to the air by being distributed throughout the fibres of cotton, as when damaged candles are heated and pressed to separate the tallow from the wicks, spontaneous inflammation is liable to ensue. If paper, linen, tow, wool, cotton, straw, wood, shavings, moss, or soot, be imbued slightly with linseed or hemp seed oil, and exposed to the sun and air, especially when wrapped up, or piled so as to form a heap, spontaneous heat, smoke, or ultimately combustion, is apt to follow. If linseed oil and pulverized peroxide of manganese be triturated together, a soft lump, formed of the mixture, will soon become ignited.\*

## OF VOLATILE OILS.

*Of the Resemblances and Dissimilarities of the Fixed and Volatile Oils.*

5069. Volatile oils resemble fixed oils as respects combustibility, solubility in ether, and insolubility in water. They may, however, be considered as much more liable to inflammation than fixed oils, and as not being so utterly insoluble in water.

5070. As fixed oils do not vaporize without being subjected to a heat adequate to effect their partial decomposition into vapour or gas, they take fire only when in contact with an ignited body sufficiently large in proportion to raise them to a red heat. Hence a comparatively small quantity of a fixed oil, poured upon embers, causes a copious inflammation; but if the quantity be sufficiently increased, the embers may be extinguished by being cooled below ignition, and shielded from contact with the air.

being allowed to cool, and to remain at rest, by depositing a yellow mucus it becomes, after a few days, clear, and may be decanted from the sediment, forming an excellent varnish. Report on Chemistry, by Berzelius, for 1841, page 148.

\* By the reaction with nitric acid, or still better with the red fumes of nitrous acid, olein is resolved partly into another fat oil, called elaidine, consisting of a fat acid, distinguished as the elaidic, and glycerine. At the same time an orange red oil is separated.

Elaidine, by the usual process of saponification, gives up the glycerine with which it is united, to the alkali employed. The resulting elaidate may be decomposed by a stronger base, and elaidic acid liberated, of which the formula, when crystallized, is  $C^{18}H^{32}O^2 + 2HO$ , being a bibasic acid. The orange-coloured oil, formed simultaneously with elaidic acid, has not been well examined.

Pure elaidic acid fuses at  $113^{\circ}$ , and is soluble both in alcohol and ether.

In the reaction of olive oil with nitrate of mercury, by which citrine ointment is made, both elaidic acid and the orange-red oil are produced. To the latter the characteristic smell and hue of the ointment is attributed.

5071. Agreeably to the principle of inverting a lighted candle causes an extension of the flame. On the other hand, any volatile oil in the vicinity of an ignited body forms, on contact with the air, a superstratum of vapour intermingled with a superabundant oxygen, so as to constitute an inflammable mixture. Hence the approach of any thing ignited or inflamed, causes a conflagration of the whole surface. This makes it evident wherefore, in the combustion of fixed oils, as in lamps and candles, a wick is requisite, which being brought into a state of combustion at the upper extremity, and drawing up the oleaginous matter by capillary attraction, causes minute portions to be successively subjected to the heat requisite to a decomposition into the combustible gas and vapour, by which flame is, in such cases, supported.

5072. Although volatile oils may be described as immiscible with water, they are not like those of the other class *perfectly* insoluble in that liquid. Hence rose water, cinnamon water, peppermint water, as well as many analogous preparations, are formed by the union of a minute portion of an essential oil with water, during its distillation from the native product containing the oil, or from a portion of it previously procured.

5073. Water by agitation with a fixed oil, may acquire a savour resembling that associated with the oil, but this is owing to a solution of the foreign matter to which that savour is due, rather than the presence of the oil itself. Yet the repulsion which exists between the oily, and aqueous particles, causes a surprisingly rapid distribution of oleaginous liquids over the surface of the water, so that it is difficult to remove every trace of greasiness after it has been imparted. It is in consequence of this property that oil has been found to abate the size and duration of waves by lessening that hold of them, taken by the wind, to which they owe their existence.

5074. The great affinity existing between fixed and volatile oils, renders it possible to combine them in any proportion. The volatile oil, being usually the most liquid, is considered as the solvent, and this appears especially proper, when oil, in the solid form of fat, is taken up by them. Hence the efficacy of oil of turpentine in removing paint, which consists of a drying oil and the metallic compound, forming the pigment. Hence, also, the oil of turpentine

is used to attenuate paints and varnishes, made with siccativ oils.

5075. The readiness with which fixed oils imbibe those of the volatile kind, has led to their employment in securing the delicate essences of certain flowers. The odoriferous petals being stratified between alternate layers of carded cotton, imbued with an inodorous fixed oil, their essence is taken up by the latter, and is subsequently separated by distillation with water.\*

### *Of Volatile Oils in particular.*

5076. After the efforts made in the preceding pages, to discriminate fixed from volatile oils, it must be evident, that the latter are distinguished from the former, by susceptibility of spontaneous evaporation, and of being distilled with the steam of boiling water, by greater inflammability, the absence of greasiness, superior solubility in water or alcohol, and lastly, an insusceptibility of being decomposed by alkaline and other bases, so as to yield to the latter saponifiable, oily acids. Like fixed oils, many volatile oils consist of a more fluid, and a less fluid oil, of which the former is, of course, more readily congealed by cold. They are also prone, like fixed oils, to absorb oxygen, and to have a portion of their hydrogen removed by uniting therewith; being thus partially converted into a resinous mass, which remains in solution in the rest of the oil.

5077. By some chemists, the less fusible or liquid portion is called stearopten, the more liquid part, elaopten. By others, the words stearessence and oleëssence are substituted, respectively, for the names above mentioned.

5078. In some respects there is a great analogy in the properties of volatile oils and ethers. The latter as respects volatility, incapacity to mix with water, solubility in alco-

\* For removing oils from clothes, oil of turpentine or any other volatile oil may be used, but followed by some inconvenience from the smell of the oil enduring for some time afterwards. By enclosing the greasy spot between folds of blotting paper, and applying a hot smoothing iron to the paper, the oil is drawn up by capillary attraction; and the more readily if its bulk and fusibility be previously increased by the addition of an essential oil.

It is by capillary attraction that moistened clay, in drying, draws grease out of a floor; and in like manner leather is, by previous moistening, made to take up oil, applied to it superficially, as the moisture is vaporized.

Strong alcohol, especially when hot, may be used to extract grease; also aqua ammonia, or the alcohol and ammonia, without being heated, may be united for this purpose, with still greater effect.

hol, and ability to unite in all proportions with volatile oils, cannot be distinguished from them. But as to composition there is no analogy; while between fixed oils and certain ethers, both consisting of acids in union with an oxidized compound radical, the analogy in composition is perfect.

5079. Volatile oils may be arranged into several sets, or classes, according to their origin.

5080. 1st. Oils directly produced by vegetables and extricated by pressure, heat, or solvents, so as to be obtained in their native state.

5081. 2d. Oils which result from the reaction of the proximate elements of vegetation, as the oil of bitter almonds, of spirea, and black mustard seed.

5082. 3d. Oils which have been produced by the reaction of their ultimate elements during destructive distillation, or by the reaction of organic substances with chemical agents. Among these we may place mineral naphtha, coal naphtha, kreosote, camphogen, caoutchoucine, and a great variety of liquids resulting from the exposure of bituminous or resinous substances to heat.

5083. It must be evident that for almost every flower and fruit, as well as many leaves and roots, there is an appropriate odour; and moreover, that in some instances, as in that of the orange, different parts of the same plant will be productive of different odours. In all cases where such odours are observed, we have good reason to infer the existence of a peculiar volatile oil. It is plainly among the wonders of the creation, that such diversity of properties should be found in substances of which a great number consist, as far as chemical skill can determine the question. of only two ultimate elements, carbon and hydrogen, which are severally, when isolated and pure, inodorous. Many different kinds of non-oxygenated volatile oils are composed of these elements in the same proportion.

5084. The volatile oils generated by vegetation, are generally extricated by subjecting the substance containing them to distillation with water, when, agreeably to the Daltonian law (229) that one vapour acts as a vacuum to another, a portion of the oil comes over, bearing the same ratio to the aqueous steam, that the tension of the one vapour in vacuo would have to that of the other. Thus, supposing that at  $212^{\circ}$  the oil would boil, when within the containing



essel the pressure should be equal only to five inches of mercury, while the aqueous steam may be formed under a pressure of 30 inches, then the vapour which would come over when they are both subjected to distillation at  $212^{\circ}$ , would be a mixture of five volumes of steam for one of vaporized oil.

5085. Some oils are obtained by expression, those of the skins of oranges and lemons for instance, while others are procured by maceration in fixed oils (5075), which, when odorless, may be used as a vehicle for their subsequent application, or may be made to give them up by distillation with water, as already mentioned.

5086. Ether may be advantageously employed to isolate volatile oils. It is an excellent solvent of them, and when quite pure evaporates, leaving them unchanged.

5087. When distilled or evaporated without protection, there is a reaction between them and atmospheric oxygen, or other impurities, by which more or less resin is generated. Hence, when used as solvents for resins, they do not dry off as well as alcohol or ether. The affinity which oil of turpentine has for some resins, common resin among others, is so great that mere evaporation in the air never causes its entire removal from them.

5088. By agitation with diluted sulphuric acid with alcohol, or preferably with a solution of chloride of calcium in alcohol, the resin may be removed from an essential oil, as is shown by the colour imparted to the detergent liquid, and the diminution of that of the oil.\*

5089. According to Graham, the odour of essential oils is due to oxidizement, since no oil has any smell immediately after its distillation, in an atmosphere of carbonic acid. This may afford an explanation of a fact, which I have long noticed, that an alcoholic solution of a volatile oil has more odour than the oil when isolated. Hence the importance of keeping such substances in well closed bottles must be evident.

5090. The inflammation of an essential oil by concentrated nitroso-nitric acid, has been shown. A compound results from its reaction with them, when inflammation

\* A small proportion of alcohol, and also of water, is liable to be held by essential oils. This may be removed by chloride of calcium. In fact, this chloride has been recommended lately to be used, in order to detect the falsification of such oils by alcohol. If, on adding a lump of anhydrous chloride to the oil, no change in the surface is perceived, the oil may be considered as free from both alcohol and moisture.

does not ensue, which has not been well examined. With iodine some of the volatile oils have an explosive reaction.

5091. Volatile oils, at a high temperature, dissolve much sulphur, and a small proportion of phosphorus, and are in some degree soluble in several vegetable acids, as for instance, acetic, oxalic, succinic, and the oily acids. With the exception of oil of cloves, of cinnamon, and of cedar wood, they do not form compounds when heated with alkaline or earthy bases. They are not susceptible of saponification. When triturated with sugar they are more ready to mingle with water. They are excellent solvents of the fixed oils, fat, spermaceti, wax, and generally for resins. Agreeably to my observations, the volatile oils, especially those containing oxygen, absorb sulphurous acid copiously; and even when washed with liquid ammonia, do not give all the elements of the acid, but retain it, probably in the state of hipposulphuric acid.

5092. The density of native essential oils varies between 0.750 as in the case of that of coriander, and 1.096 in the instance of oil of sassafras.

5093. From caoutchouc, or gum elastic, an oil has been obtained of the density of .670, which is much less than that of any native oil evolved from vegetables.

5094. Volatile oils, in general, absorb six or eight times their volume of ammoniacal gas; but the oil of lavender absorbs 47 times its volume.

5095. Oil of turpentine absorbs one-fifth of its volume of carbonic acid; nearly double its volume of carbonic oxide; twice its volume of olefiant gas; 27 per cent. of nitrous oxide, and five times its volume of cyanogen.

5096. Volatile oils are converted into resins by those metallic oxides which are readily deoxidized: also by the chlorides of tin and of antimony. What is called Starkey's soap, obtained by triturating oil of turpentine with an alkali, is a combination of a resin, produced during the process, with the alkali employed.

#### *Volatile Oils containing Sulphur as an ultimate Element.*

5097. The presence of sulphur in the volatile oils, which come under the preceding designation, forms a remarkable exception to the prevailing composition of such oils. The

tile oils of black mustard seed, of horse-radish, of onions, of asafœtida, of water pepper, of hops, and some others, contain sulphur.

*Volatile Oil of Mustard,  $C^8 H^5 NS^2$ .*

098. This oil is obtained, by distillation with water, from the black mustard seed, being, it is alleged, the result of the reaction of an albuminous constituent called myrosin, and an acid denominated myronic acid. Volatile oil of mustard is colourless, heavier than water, affecting the olfactory nerves so painfully as to induce tears, and producing inflammation and blisters on contact with the skin. Its boiling point is 289.4. When inflamed, it gives fumes of sulphurous acid. By distillation from hydrated oxide of iron, it is deprived of its sulphur, and resolved into ammonia and a crystalline substance called sinapoline.

099. From the formula it will be seen that this oil contains one atom of nitrogen, as well as two atoms of sulphur. From the contact of this oil with ammonia in a closed phial, a crystalline compound is formed, supposed to be an amiduret. Of this the formula is  $C^8 H^5 NS^2 NH^3$ .

100. The remarks which were made respecting the inadequacy of treating of fixed oils in detail, apply equally to the case of the volatile oils.

101. For information respecting their medical properties, their botanical relations, and the processes of extracting them, where they are among the articles of the materia medica, reference may be had to the United States Dispensatory.

102. It has been mentioned that there are two classes of oils; one containing oxygen, the other devoid of that element. The following tables of the more important volatile oils, with and without oxygen, are given by Kane.

*Volatile Oils containing Oxygen.*

Plant yielding the Oil.	Sp. gr. as Liquid.	Boiling Point.	Formula.	Sp. gr. of Vapour.
Cajeput . . . .	0.927	347°	C <sup>10</sup> H <sup>8</sup> O	
Lavender . . . .	0.896	397°	C <sup>15</sup> H <sup>14</sup> O <sup>2</sup>	
Rosemary . . . .	0.897	365°	C <sup>45</sup> H <sup>36</sup> O <sup>3</sup>	
Pennyroyal . . . .	0.925	395°	C <sup>10</sup> H <sup>8</sup> O	
Camphor tree . . . .	0.910		C <sup>20</sup> H <sup>16</sup> O	
Valerian . . . . .		518°	C <sup>20</sup> H <sup>18</sup> O	
Spearmint . . . .	0.914		C <sup>25</sup> H <sup>20</sup> O	
Marjoram . . . . .	0.867	354°	C <sup>50</sup> H <sup>40</sup> O	
Asarum . . . . .			C <sup>16</sup> H <sup>8</sup> O <sup>3</sup>	
Fennel . . . . .	0.997		C <sup>20</sup> H <sup>18</sup> O <sup>2</sup>	
Anise . . . . .			C <sup>20</sup> H <sup>18</sup> O <sup>2</sup>	
Peppermint . . . .	0.902		C <sup>21</sup> H <sup>20</sup> O <sup>2</sup>	
Rue . . . . .	0.837	446°	C <sup>28</sup> H <sup>22</sup> O <sup>2</sup>	7600
Olibanum . . . . .	0.866	323°	C <sup>25</sup> H <sup>20</sup> O	
Cumin . . . . .	0.860	418°	C <sup>20</sup> H <sup>18</sup> O <sup>2</sup>	5004

*Volatile Oils devoid of Oxygen.*

Plant yielding the Oil.	Sp. gr. as liquid.	Boiling Point.	Formula.	Sp. gr. as Vapour.	Circular Polarising Power.
Citron . . . .	0.847	343°	All these oils have the same composition expressed by the formula C <sup>3</sup> H <sup>4</sup> .	All these oils give vapours with the specific gravity, = 4766.	+ 80° 9, right
Copaiva . . . .	0.878	478°			+ 34° 2, left
Parsley . . . .		410°			
Juniper . . . .	0.839	311°			— 3° 5, left
Savine . . . .		315°			
Cubebs . . . .	0.929				— 40° 1, left
Black Pepper . .					
Bergamotte . .					+ 29° 3, right
Turpentine . .	0.864	315°			— 43° 3, left

5103. Generally, essential oils containing oxygen may be separated into an acid and an oil destitute of oxygen, by reaction with fused hydrate of potash. Thus, from oil of valerian, valerianic acid has been obtained, and an oil which, absorbing oxygen rapidly, is converted into common camphor.\* Oil of cumin, by similar treatment, yields cuminic acid, which is analogous with benzoic acid, and is conjectured to have a relation to a peculiar compound radical, cumyl, analogous to that which the acid last mentioned, has to benzule or benzyl.

\* Gerhardt and Cahours.

4. The composition of all the essential oils free from n, may be represented by  $C^5 H^4$ , their formulas being multiples of these numbers. Turpentine has the formula  $H^{16}$ ; cubebs  $C^{15} H^{12}$ ; and the rest  $C^{30} H^8$ .

5. Kane observes, that an examination of the tables given, will make it appear that all essential oils are multiples of  $C^5 H^4$  with oxygen and water.

6. *Of Oil of Turpentine.*—This is the cheapest, and by much the most used of all the volatile oils, and has a good exemplification of an essential oil devoid of oxygen. When pure, it is as colourless and limpid as water. Its volatility, inflammability, hot pungent taste, agreeable smell, recalling that of camphor, are well known. At  $72^\circ$  F. its density is .86. Its boiling point is above  $300^\circ$ . In water it is but minutely soluble, and in alcohol only takes up about one-seventh of its bulk. When heated, it takes up a larger proportion, which is deposited by refrigeration. As found in commerce, oil of turpentine is said to contain oxygen, whereas, in truth, it is a resin, in which that element is a constituent, and from which it may be freed by distillation with water, or by extraction either with alcohol, with diluted sulphuric acid, or with an alcoholic solution of chloride of calcium. In the diversity of the two compounds formed with it, and of the hydroxylic acid, there cannot be a doubt that it consists of two volatile oils differing but little in composition. These are alleged to give rise to two different resins, one in the rosin which is associated with it in its native state. See artificial camphor, camphene, &c. 5112, 5114.

It is usually distilled, and after being carefully purified of any resinous matter, oil of turpentine has been found capable, lately, of being burned in Argand lamps of a simple construction, and of giving a light much more intense than that produced by oil, wax, or gas.

But, the excess of carbon which makes the flames of volatile oils too fuliginous when subjected to combustion in ordinary lamps, is, in the case in point, the defect of the superior light, as it is well known that the intensity of the illumination is in proportion to the quantity of carbon oxidized in a given space.

The colour of oil of turpentine, and a flocculent deposition of carbon, notwithstanding there is no apparent association of such matter with the flame; also the danger in case of fire resulting from the presence even of a small quantity of inflammable liquid, are the great objections to the general use of this brilliant method of illumination. For streets and light-houses, where gas is employed advantageously, a resort to this process may be highly expedient.

Principles already adverted to, by which a liquid in contact with matter in a state of vaporization, will be vaporized proportionably to the tension of the vapour which would form in vacuo at that temperature, are brought into play when a solution of turpentine in alcohol is burned in lamps of an appropriate form. This conclusion is founded upon experiments made by myself more than twenty years ago,

*Of Camphor.*

5107. Camphor,  $C^{20} H^{16} O^2$ , or  $C^{20} H^{14} + 2HO$ , seems to have a relation to the volatile oils, resembling that of stearine or spermaceti to the fixed oils, being a species of concrete oxidized volatile oil. It is represented as the stearopten of the oil of camphor. Its consistency, smell, taste, solubility in alcohol, in ether, and in the fixed and volatile oils; also its insolubility in water, and susceptibility of volatilization or evaporation in the air, are well known. Camphor fuses at  $347^\circ$ , boils at  $399.2^\circ$ . Its density in the solid state, as compared with that of water, 0997; in the state of vapour, as compared with air, 5317.

5108. By repeated distillations with anhydrous phosphoric acid, it loses two atoms of water, and is reduced to the state of a colourless liquid hydruret of carbon,  $C^{20} H^{14}$ , of the density of .861 at  $57^\circ$ , being denominated by Demas, its discoverer, camphogen. Camphogen is analogous to benzole or naphthaline.

5109. Liquid camphor,  $C^{20} H^{16} O^1$ , is a product of the same tree as concrete camphor, and contains a more liquid portion, and less liquid portion. The former, the elaopten, differs from concrete camphor in containing only half as much oxygen. Its density is less than that of the solid camphor. In composition, the latter differs from oil of turpentine only in the presence of two atoms of oxygen; liquid camphor in the presence of one atom of the same element.

5110. An interesting account of this substance will be found in the United States Dispensatory.

5111. Other volatile oils, besides that of the camphor tree, yield stearopten analogous to camphor. Of such oils Kane gives the following table:—

when I used a mixture of six parts of alcohol, and one of oil of turpentine, in an Argand lamp.

Subsequently, however, on being consulted, I objected to the use of the contrivance on account of the danger arising from its liability to inflame. Experience has shown, by many melancholy disasters, that this counsel was correct.

Not giving the Camphor.	Sp. gr. as Liquid.	Melting Point.	Boiling Point.	Sp. gr. of Vapour.	Formula.
Os (Otto) .		77°	550°		CH
Sley . .		70°	552°		C <sup>13</sup> H <sup>7</sup> O <sup>4</sup>
Florentina					C <sup>4</sup> H <sup>4</sup> O
campane .		108°			C <sup>7</sup> H <sup>5</sup> O
rum . .		104°	530°		C <sup>16</sup> H <sup>11</sup> O <sup>4</sup>
nel . .	1.014	68°	428°		C <sup>20</sup> H <sup>13</sup> O <sup>3</sup>
se . . .		64°	430°	5680	C <sup>20</sup> H <sup>13</sup> O <sup>3</sup>
peppermint .		91°	406°	5455	C <sup>21</sup> H <sup>20</sup> O <sup>3</sup>
cebs . . .					C <sup>16</sup> H <sup>14</sup> O
terpine . .	1.057	302°	311°		C <sup>20</sup> H <sup>20</sup> O <sup>4</sup>

in comparing these formulæ with those of the corresponding oils, it is seen that camphors arise from very various causes; in some cases they are isomeric with olefins, in others oxides of them, and in others hydrates; thus, the camphor of turpentine may be formed at will, by agitating the oil with water and then exposing it to the air; the hydrate crystallizes out in colourless prisms, sometimes of great size. The peppermint camphor has been found to yield, by the action of reagents, a series of compounds. Thus, by the action of glacial phosphoric acid, or of oil of vitriol, a light oil was obtained, having the formula C<sup>21</sup> H<sup>18</sup>, which is termed menthene. By the action of chlorine, a thick heavy liquid is produced, C<sup>21</sup> H<sup>14</sup> Cl<sup>6</sup> O<sup>2</sup>. Nitric acid, menthen yields a heavy oily liquid, C<sup>21</sup> H<sup>18</sup> O<sup>2</sup>, which possesses acid properties; and with chlorine, menthen yields a syrupy yellow liquid, having the formula C<sup>21</sup> H<sup>13</sup> Cl<sup>8</sup>.

### Artificial Camphor.

112. If one hundred parts of oil of turpentine, refrigerated by snow and salt, be saturated with chlorohydric gas, by means of an impregnating apparatus, a quantity of the gas, equal to about one-third of the weight of turpentine, is absorbed. Meanwhile the turpentine is changed into a soft crystalline mass, from which, allowing it to drip for some days, about twenty parts of a colourless acid liquor are obtained, charged with many crystals, and one hundred parts of a white, granular, crystalline substance, which so much resembles camphor in odour and volatility, that it has received the same appellation.

113. Artificial camphor is lighter than water. It does not redden litmus. It may be sublimed, but not without partial decomposition. If passed through an incandescent tube, it is resolved into its constituents. It dissolves in alcohol, and is precipitated from it by water unchanged. Chlorine is disengaged from it by nitric acid. This substance has been analyzed both by Dumas and Oppermann. According to the former chemist, it is composed of one volume of chlorohydric acid united to one volume of a

compound, formed of ten atoms of carbon and eight of hydrogen, and consequently identical in composition with pure oil of turpentine.

*Of Camphene or Camphelene, and Terebene.*

5114. From artificial camphor, by subjection to the distillatory process with quick-lime, an oil separates, called, by Dumas, camphene, by others, camphelene. This oil is identical in composition with pure oil of turpentine, and differs from it so little in properties, that were it not that the latter has a power of causing a pencil of polarized rays to turn to the left, of which power the former is devoid, one could not be distinguished from the other. The liquid from which the artificial camphor crystallizes, has the smell of camphor no less than the crystalline portion, and consists of nearly the same ultimate elements, united to chlorohydric acid. It has a relation to artificial camphor like that which the eleapten of a volatile oil bears to the stearopten. When this liquid artificial camphor is distilled with sulphuric acid at as low a heat as possible, an oil is obtained, called terebene, which is, like camphene, devoid of the power of causing any rotation in polarized rays. Yet either terebene or camphene, by uniting again with chlorohydric acid, may regenerate each the kind of artificial camphor from which it was evolved, and in this respect they differ from each other, with differing from the pure native oil as already stated. Yet, by combining with chlorine, both camphene and terebene acquire a power of causing, in polarized light, a rotation in a direction the opposite of that produced by the native oil of turpentine (4052).

*Of Kreosote.*

5115. This name has been given to an essential oil, to which allusion has been above made, as one of the products of the destructive distillation of vegetable matter. It is represented as highly interesting and important, on account of its efficacy as a medicine, and in preserving meat; being in fact considered as the principle to which pyroligneous acid and wood smoke are indebted for their antiseptic powers, and tar-water for its medicinal virtues.\*

5116. Kreosote is elaborated either from crude pyroligneous acid, or from wood tar, by a series of distillations, and subjection to different agents.

5117. Besides its activity in medicine, kreosote is alleged to have energetic powers as a chemical agent. It is an oleaginous, colourless, transparent, and highly refracting liquid. It has the smell of crude pyroligneous acid, or of smoked meat, and its taste is caustic and burning. To

\* The antiseptic power of oil of cloves, and still more that of oil of cinnamon, are equal to those of kreosote, agreeably to my experiments made with meat or cream. A few drops of cinnamon oil added to a paste of gum tragacanth, will prevent, for months, the fetor which otherwise is soon acquired.



to touch it is a little greasy, and its consistency is similar to that of the oil of almonds. It is rather heavier than water, being of the specific gravity of 1.037. It boils at 97°.

5118. Kreosote is devoid of acid or alkaline reaction. With water it forms two combinations—one a solution of one part of kreosote in four hundred of water, the other a solution of one part of water in ten of kreosote. It unites in all proportions with alcohol, ether, and naphtha, and is capable of dissolving a large quantity of iodine and phosphorus, and likewise sulphur, especially when assisted by heat. Agreeably to Thenard, the composition of kreosote is expressed by the formula,  $C^{14} H^9 O^2$ .

### *Of Essential Oils which are Hydrurets.*

5119. Among the oils which may be called hydrurets, are the hydruret of benzule or oil of bitter almonds; an oily hydruret existing in the commercial oil of cinnamon or cassia, called hydruret of cinnamyl; the oil of spirea lmaria or hydruret of salycyl; and the hydruret of cumyl, derived from the oil of cumin. Of the three first mentioned oils, some account has been given in treating of their radicals; and to the hydruret of cumyl, allusion was made in paragraph 5103. I do not, however, deem it expedient to give any details here respecting any of these oils, excepting the hydruret of benzule. Of this I shall treat for the purpose of exemplification.

### *Of the Hydruret of Benzule, or Oil of Bitter Almonds.*

5120. The formula of this hydruret is  $C^{14} H^5 O^2 + H$ , or BZ + H. By distilling bitter almonds, or the leaves of cherry laurel, with water, a volatile product comes over, consisting of a mixture of the hydruret of benzule, of benzoic acid, of gum benzoin, and cyanhydric acid. In order to extricate the hydruret from this mixture, a second distillation is requisite, with the previous addition of chloride of iron, hydrate of lime, and sufficient water to liquefy the whole. Under these circumstances, the oil may be distilled, accompanied by water, which may be separated by the usual means, and subsequent agitation with chloride of calcium.

5121. *Properties.*—This hydruret is colourless and transparent, refracting light strongly, being endowed with a strong odour like that of cyanhydric acid, and a hot taste. Its specific gravity is 1.043; its boiling point 256°. It is soluble in thirty parts of water, and in alcohol in proportion. Its vapour may be transmitted through a red-hot tube without decomposition. It burns with a white, though smoky flame. By absorbing two atoms of atmospheric oxygen, one to unite with an atom of hydrogen, the other to take its place, this hydruret is converted into benzoic acid. Sub-

jected, at a high temperature in close vessels, to hydrate of potash, it forms a benzoate of that base by absorbing the oxygen, and liberating the hydrogen of an atom of water.

5122. The hydruret of benzule undergoes no change by being in contact with aqueous solutions of caustic alkalies or earths, but, while thus situated, a few drops of cyanhydric acid will enable crystals of benzoin to be generated.

5123. By contact with chlorine or bromine, the hydruret of benzule is converted into chloride or bromide, its hydrogen being simultaneously converted into chlorohydric or bromohydric acid, by uniting with one or the other of those elements.

5124. An iodide of benzule can be obtained by the reaction of the chloride of this compound radical with the iodide of potassium; in like manner a sulphide, by the distillatory reaction of a chloride with the sulphide of lead; and a cyanide, by substituting a cyanide of mercury and resorting to the same means.

#### *Of the Amiduret of Benzule or Benzamide, BZ NH<sup>a</sup>.*

5125. From the preceding formula it must be evident that the compound, of which the name is above given, consists of benzule, and the compound radical, amide.

5126. This amiduret arises from the reaction of the chlorides of the same radical with dry ammonia. It is likewise evolved by the reaction of hippuric acid with the peroxide of lead.

5127. Amiduret of benzule crystallizes in right rhomboidal pearly prisms or tables. A hot concentrated solution by refrigeration, yields a soft mass of very fine crystalline needles, which are gradually transformed into broad colourless laminæ. These crystals melt at 239° into a colourless liquor, and at higher temperatures are susceptible of forming an inflammable vapour. They are soluble either in water, alcohol, or ether.

5128. Water being present, alkalies or acids resolve this amiduret into ammonia and benzoic acid. On being heated with anhydrous baryta, a benzoate of this base is produced, with a disengagement of ammonia, much heat, and the volatile oil called benzole. Similarly treated with potassium, a cyanide of this metal results, with the evolution of an oleaginous aromatic liquid of a slightly sweet taste. The hydruret of benzule unites also with anhydrous formic acid, generating a compound acid called formobenzoic acid; also with benzoic acid, forming what is by Liebig termed a benzoate of the hydruret of benzule.

#### *Of Resins.*

5129. Resin is now the generic name of a class of bodies, of which common resin or rosin is an exemplification, having had its name extended to the class in consequence of their analogy with it. On this account, English writers have latterly used the word resin, generally employing the word rosin as the name for the substance which formerly was designated either as *resin* or *rosin*. In pharmacy, rosin is also known as colophony or colophonium; especially on the continent of Europe.

5130. Resins are found in vegetables and in the fossil state, as in the instance of amber and asphaltum; but in every case, are considered as having been originally the products of vegetation.

5131. In vegetables, resins exist more or less in combination with essential oils; and I believe them to be generally produced by the reaction of such oils with oxygen. It has been mentioned that, when distilled per se, almost every volatile oil is liable to be partially converted into a resinous substance, which does not come over. It is also true, that any resin, exposed to destructive distillation, gives rise to more or less pyrogene oils of the volatile kind, as well as carburetted hydrogen, and carbonaceous depositions, and residues.

5132. In many cases, as in that of the turpentine of commerce, the compound formed by the resin and the volatile oil with which it is naturally associated, is sufficiently liquid to flow from incisions made through the bark and sap wood. It is thus that the copious supply of turpentine found in commerce, is obtained from the long-leaved pine of the Carolinas.

5133. Another portion of resinous matter, expelled by fire, forms the tar of commerce. This contains some remarkable volatile compounds generated by heat, called paraffine, eupion, and kreosote. The former is a concrete oil, the others liquid. Tar also contains acetic acid in combination with the several peculiar resins, called *pyrene*, or *pyrogene* resins, by Berzelius.

5134. As the expulsion of resinous matter by the tar-producing process destroys the peculiar properties of resins, I believe it is not resorted to in obtaining resins in other cases. More valuable resins, which do not spontaneously exude, are generally extracted by digesting the vegetable product containing them in alcohol. From the alcoholic solution, when it takes up other substances, the resin is precipitated by water.\*

\* The celebrated varnish of the island of Japan exudes from the rhus vernix, which is among the forest trees of the United States, being notorious for its poisonous influence on some persons, while to others comparatively harmless. The active principle to which its poisoning power is due, would be a worthy object of investigation by any one not susceptible of the injurious effects alluded to. In the art of varnishing in this country and in Europe, other substances are made to imitate the effect of the real Japan varnish, named from the country in which it is employed.

5135. Resins are all insoluble in water, and for the most part, directly or indirectly, soluble in alcohol, and in volatile and fixed oils. They cannot, like volatile oils, be distilled with the aid of water. When subjected, *per se*, to the distillatory process, they are decomposed, as above mentioned, into carburetted hydrogen, carbon, peculiar resins, and volatile oils, some acids, and more or less carbon partly in the state of lamp-black, partly in union with the other products, whence their dark or black colour.

5136. In few instances do resins assume a crystalline form. They are brittle when pure, and generally translucent, rarely colourless, having, commonly, various hues of yellow or brown, but sometimes green or red. There is a great resemblance in properties between resins and concrete oils, such as suet, tallow, spermaceti.

5137. Resins are distinguished by a greater hardness and tenacity, and in being sticky to the touch instead of being greasy. Hence rosin serves to create the necessary attrition between the hair of the bow and the strings of the violin, which is an effect the opposite of that for which oil is used in machinery. In this, as well as in other respects, wax approaches the resins in character more than any other concrete fixed oil. But this adhesiveness is much increased by heat, so that at ordinary temperatures copal, amber, and many other resins, are not sticky. In consistency resins much resemble gums, but are distinguished from them by insolubility in water, and solubility in fixed and volatile oils, and generally in alcohol and ether.

5138. Some resins resemble fixed oils, in containing two substances, of which one is more soluble, the other less soluble in alcohol. This characteristic is, in some instances, displayed in their habitudes with some essential oils. Rosin, for instance, is said to be only partially soluble in naphtha.

5139. Resins, also, are susceptible of saponification, so far as to combine with alkaline and other bases forming salts, in which the base, being imperfectly neutralized, possesses the deterative power. It is well known that rosin is a constituent of common brown soap, yet, according to Ure, it cannot enter into it advantageously beyond the proportion of a third. There is this important difference, however, in the phenomena of the reaction of fixed oils

bases, and that of resins, that there is no base to be called analogous to the oxide of glyceryl.

40. Concentrated nitric acid and resins react, in some cases, with an explosive ignition. According to Berzelius, resins dissolve in concentrated sulphuric acid, *when cold*, without decomposition, although when hot reciprocal decomposition ensues. I have ascertained that sulphuric acid forms, either with oil of sassafras, or with oil of turpentine, resins, by which it is coloured to a miraculous degree, since a six-millionth part suffices to create a rosy tint. A similar effect, in an inferior degree, ensues from the presence of oil of cloves. To the resins thus produced, I have given the names of sassarubrin and cinnarubrin. I believe in any case it will be found, that more or less colour is produced by the reaction of concentrated sulphuric acid with essential oils. In fact, such oils, to a certain extent, act as bases to this acid, diminishing the sourness of a diluted solution, and when such a solution is saturated with ammonia, a resin formed from the oil separates.

41. Resins are soluble without alteration, either in ether or chlorohydric acid.\*

42. Prof. F. W. Johnson has proposed to represent resins by two general formulæ, either of which contains

appears from Unverderben's laborious investigations, that by the various uses of hot alcohol or ether, resins, as they are found in nature, may be resolved into various substances, differing from each other as respects readiness to combine with acids; so that he has classed them as resins strongly electro-negative, moderately electro-negative, feebly electro-negative, and indifferent. This author founds his variety of designation, on their greater or less disposition to combine with lime, carbonate of soda, or caustic alkaline solutions.

According to Johnson's Report to the British Association, for 1832, Buchner and Gerger had described some resins as having weak basic properties. Resins extracted from jalap and euphorbium had each been found a compound of two resins, one acid, the other a weak base: also all drastic gum resins were considered by chemists as similarly compounded.

It is well known that all resins are electrics, and by friction become negatively charged.

According to the author last mentioned, sandarach is a mixture of three resins; of which five; benzoin of three; guaiac of two; and lac and colophony of several.

When rosin or colophony is subjected to cold alcohol, of the density of 867°, one part dissolves, called alpha resin or pinic acid; while another remains, called beta resin or sylvic acid. By exposing pinic acid to distillation, another acid is generated called colophonic. Again, the solution of pinic acid may be decomposed by acetate of lime, of which the oxide precipitates with the acid, leaving an indifferent resin solution.

White rosin, from the pinus maritima, consists of an acid, crystallizable resin, and pimaric acid. Distilled in vacuo, pimaric acid gives rise to another, called pimaric acid. Boiled with nitric acid, pimaric yields azomeric acid. But there is no variety of compounds resulting from subjecting resins to heat and solvents. It may be of some practical importance to know, that resins are not simple substances, and that even the rosin of different trees may contain different acids.

forty atoms of carbon, while one holds from sixty to sixty-eight atoms of hydrogen, with from one to twenty of oxygen; the other, forty to fifty-four of hydrogen with from seven to fourteen atoms of oxygen.

5143. He infers, that the resin of scammony,  $C^{40}H^{30}O^9$ , extracted from crude scammony by alcohol, contains the largest quantity of oxygen of any resin hitherto analysed; and that the resin of jalap, obtained by evaporating the alcoholic extract, and subsequent boiling in water, of which the formula is  $C^{40}H^{34}O^{18}$ , is, as respects the quantity of contained oxygen, surpassed only by scammony.

5144. Agreeably to the same author, there is a striking relation between the formulæ of the resins of ammoniac and asafœtida, the former being  $C^{40}H^{25}O^9$ , the latter,  $C^{40}H^{26}O^{10}$ , as if the one were merely a hydrate of the other.

5145. Berzelius considers our knowledge of the composition of resins as yet too imperfect to justify us in placing much confidence in these suggestions of Johnson as to the grouping of all resins under two formulæ as above mentioned. Report for 1841, 171.

5146. The following list of the more important resins of commerce, with their formulæ, is taken from Kane's Elements, p. 969.

Anime Resin	$C^{40}H^{32}O$	B. Sandarach	$C^{40}H^{32}O^5$
Elemi Resin	$C^{40}H^{32}O$	A. Euphorbium	$C^{40}H^{32}O^5$
Fossil Copal	$C^{40}H^{32}O$	Asphaltene	$C^{40}H^{32}O^5$
B.* Mastic Resin	$C^{40}H^{31}O^2$	A. Olibanum	$C^{40}H^{32}O^5$
Antiar Resin	$C^{40}H^{30}O^2$	Labdanum	$C^{40}H^{32}O^5$
B. Copal Resin	$C^{40}H^{31}O^3$	Pasto Resin	$C^{40}H^{32}O^5$
Birch Resin	$C^{40}H^{32}O^3$	Sagapenum	$C^{40}H^{32}O^5$
A. Mastic Resin	$C^{40}H^{31}O^4$	Scammony	$C^{40}H^{32}O^9$
Copaiva Resin	$C^{40}H^{32}O^4$	Jalap Resin	$C^{40}H^{34}O^{18}$
A. Elemi Resin	$C^{40}H^{32}O^4$	Galbanum	$C^{40}H^{32}O^5$
B. Olibanum Resin	$C^{40}H^{32}O^4$	Dragon's Blood	$C^{40}H^{32}O^5$
C. Sandarach	$C^{40}H^{30}O^6$	Gamboge	$C^{40}H^{32}O^5$
Ammoniac Resin	$C^{40}H^{24}O^9$	A. Asafœtida	$C^{40}H^{26}O^{10}$
B. Asafœtida	$C^{40}H^{26}O^{10}$	Acaroid Resin	$C^{40}H^{32}O^{11}$
Guaiacum	$C^{45}H^{32}O^{10}$	Opoponax	$C^{40}H^{34}O^{14}$
Bdellium Resin	$C^{40}H^{31}O^5$	B. Benzoin Resin	$C^{40}H^{32}O^5$
A. Sandarach	$C^{40}H^{31}O^5$	A. Benzoin Resin	$C^{40}H^{32}O^5$

### Of Wax.

5147. This word is generally used to designate the substance of which bees make their honeycomb; more accu-

\* Where a native resin has been separated into two, by solvents, the letters A and B are used to distinguish one from the other.

ly called bees-wax. Other kinds of wax are found to n the pollen of flowers, the varnish on the upper surfaces of the leaves of certain trees, and the skins of certain ne fruit; also to be yielded by the cabbage, and in a ge proportion by the berries of several species of the rtle, *myrica angustifolia*, *latifolia*, and *cerifera*.

148. Formerly bees-wax was supposed to arise from pollen of flowers swallowed and excreted by bees; but as been proven that the wax of bees is secreted by an an situated on the sides of the medial line of the abdomen of the insect. On raising the lower segments of the lomen these sacs were observed; also the scales, or ngles of wax arranged in pairs upon each segment. . Huber ascertained that bees, while prevented from ng abroad in quest of food, and fed solely on sugar, re capable of generating wax.

149. These conclusions have been strengthened by the t, that myrtle wax yields, by saponification, stearic, rgaric, and oleic acids, and glycerine, like a true fat, ile, when subjected to the same reagents, bees-wax is able only of a partial saponification, yielding in lieu of r congener, of ethal, or of the sweet principle of oils, a stance called cerain, which differs neither in composi- n nor properties from that portion of wax which is inso- le in boiling alcohol.

150. This portion has been called myricine, while the tion dissolved in the hot alcohol is called cerine. It is ine only, that is capable even of the partial saponifica- n to which allusion has been made. As respects this aration into cerine, and myricine, by boiling alcohol, s-wax resembles a fat, consisting of stearine and mar- ine, while devoid of oleine; but in its chemical constitu- a and habitudes, with bases, it resembles the resins. ax is also destitute of the greasiness or slipperiness of , tending, when interposed between surfaces, to impede ir sliding, rather than to facilitate it like an oil. Upon whole I consider bees-wax as a substance intermediate tween a concrete fixed oil and a resin.

151. The yellow wax of commerce is obtained by fu- g, and washing, the crude wax of the comb with boiling ter. Yellow wax is converted into white wax by causing o form thin ribbons by flowing while melted upon a re- ving wooden cylinder, half immersed in water, and sub-

sequently exposing these ribbons to the solar light and the air, as in the old process for bleaching linen. The wax of the honeycomb, before being supplied with honey, is white.

5152. Pure white wax is of the specific gravity 960, 966. It is insipid and inodorous, insoluble in water, partially soluble in boiling alcohol, and perfectly soluble in essential or fixed oils. It fuses at about  $154^{\circ}$ . Its general uses are too well known to need description. Not being much acted on by acids, it is used to defend corks, and as cement or lute, for chemical apparatus.\*

*Of Caoutchouc or Gum Elastic, and Caoutchoucine.*

5153. Caoutchouc exudes, in the state of an emulsion, from incisions made in certain trees, and congeals in the form of the mould upon which it may be received. Like essential oils, devoid of oxygen, it consists only of carbon and hydrogen,  $C^8 H_7$ . As respects its chemical habitudes, it might be considered as a resin, were it not for its wonderful and peculiar elasticity, and the mechanico-chemical property of allowing gases to get through its pores with a celerity not corresponding with the minuteness of their atomic weights. In its native state, instead of being held in solution, as resins are usually, by an essential oil, it is merely suspended in water, as butter and caseine are in milk. Faraday found in a portion of caoutchouc milk which he examined, the following ingredients:—

Brown bitter azotized matter, soluble in alcohol and water, and precipitable by nitrate of lead, - - - -					7.18
Vegetable albumen, - - - -					1.9
Substance soluble in water, insoluble in alcohol, - - - -					2.9
Water holding a small quantity of free acid, - - - -					56.37
Caoutchouc, - - - -					31.7
					<hr/>
					100.00

5154. Pure caoutchouc, carefully prepared from the native emulsion, is of the density of .925, being transparent and colourless, and, when in mass, yellowish white.

5155. It is utterly insoluble in water or alcohol, but soluble in pure ether (oxide of ethyl), and likewise generally in pure essential oils, especially oil

\* *Of Cerosic.*—Mr. Avequin has examined the wax which covers the sugar cane, and the lower part of the leaves by which it is surrounded. It may be obtained by scraping the surfaces covered with it. In the violet variety of the plant in question, this wax is so abundant, that it is inferred by Mr. Avequin that it might be profitably collected for the purpose of making candles. The scrapings are digested in cold alcohol to remove impurities. Afterwards they are dissolved in boiling alcohol. The solvent being removed by distillation, the wax is isolated.

This wax is slightly yellow, hard, brittle, easily reducible to powder of a bright white, fuses at  $176^{\circ}$ , and burns like ordinary wax or spermaceti. It is less soluble in ether than alcohol. From boiling solutions in either solvent, it separates in pretty needle-shaped crystals by refrigeration. Mr. Avequin proposes for this wax the name *cerosic*, from the Greek *ceros*, wax. The formula of this wax is, according to analysis by Dumas,  $C^{20} H^{30} O^1$ .



sassafras, cajeput, and turpentine. It does not, however, readily liquefy, absorbing many times its bulk of the solvent, may be liquefied afterwards by rubbing through a sieve. It is, perhaps, even more soluble in the terogene oils, such as naphtha, whether native or as obtained from coal, and in the peculiarly volatile oil, called caoutchoucine, which it yields itself to destructive distillation, and repeated subsequent rectifications. It has been mentioned, that this oil was lighter than any analogous native product. It is, in fact, lighter and more volatile than common ether, its density being only 670, and for its boiling point 90°. From none of the volatile oils, not even caoutchoucine, have I recovered caoutchouc, without more or less deterioration. This may be presumed to arise from a minute quantity of resinous matter formed at the expense of the solvent which remains with the caoutchouc. I have found a great diversity in the solubility of caoutchouc. Neither in caoutchoucine, nor in ether, have I found the ordinary bag caoutchouc to dissolve readily. It softens and swells up, but does not liquefy. Out of a large lump of massive caoutchouc, sent to me from London by Mr. Underby, was readily liquefied either by the one or the other of the last mentioned solvents, and by the ether was deposited in a perfect state. I have not learned the source of the more soluble caoutchouc thus alluded to, nor have I met with any notice respecting this difference of solubility. Caoutchouc burns with an excessively fuliginous flame in atmospheric air, but in oxygen gives an intense light by the oxidation of the carbon forming the smoke (645). When fused, per se, it is converted into a tarry matter, which does not indurate by drying. This tar may be ignited by nitroso-nitric acid.

5156. Dr. Mitchell ascertained that caoutchouc bags, after soaking in a mixture of ether and alcohol of the specific gravity of from 750° to 780°, at the usual officinal strength, may be inflated with air, and the material of which they consist consequently extended to various degrees of tenuity, according to the peculiar character of the variety subjected to trial. Hence it may be used to make balloons, gas bags, or sheet gum elastic, which is very useful for fillets, with which to make air-tight junctures or lutings. There is no better mode of joining a tube to the tubulure of a retort, or receiver, than by tying about the tubulure the body of a small caoutchouc bag, while the tube is inserted into the neck, and carefully secured by a gature. Fused caoutchouc is useful in some cases as a lute. It will not, however, resist fuming nitroso-nitric acid.

5157. Dr. Mitchell has made some very interesting observations respecting the power of gases to pass through thin membranes of caoutchouc. By some inconceivable process, gases, which are all prone, in a greater or less degree, to reciprocal intermixture, will effect this result, notwithstanding the interposition of caoutchouc, and the opponent influence of great pressure.

5158. When a vessel filled with atmospheric air, and having the mouth closed by a caoutchouc membrane, was introduced into a vessel of hydrogen, this gas made its way into the vessel, until the membrane burst outwards; but when the vessel, while similarly closed by the membrane, and complete with hydrogen, was exposed to common air, the hydrogen escaped until the membrane burst inwards. A tube, with a trumpet-shaped mouth, being bent so as to form a syphon, and the larger orifice closed by the membrane while full of atmospheric air, a suitable quantity of mercury was poured into the syphon, until it stood in both legs at the same height. Under these circumstances, when the membrane was brought into contact suc-

cessively with different gases, they were found to enter with various degrees of celerity, as will appear from the following statement:—

	H.	N.
Ammoniacal gas - - - -	0	1
Sulphydic acid - - - -	0	2½
Cyanogen - - - -	0	3½
Carbonic acid - - - -	0	5½
Protoxide of nitrogen - - -	0	6½
Arseniuretted hydrogen - - -	0	27½
Olefiant gas - - - -	0	28
Hydrogen - - - -	0	37½
Oxygen - - - -	1	13
Carbonic oxide - - - -	2	40
Nitrogen - - - -	3	15

5159. The gases continued in some instances to enter until the mercury in the longer leg rose to the height of sixty inches.

5160. It is quite surprising that the atoms of ammonia should pass through the membrane with greater celerity than those of hydrogen, when each of the former consists of three of the last mentioned gas, united with one atom of nitrogen. Also that two atoms of oxygen, while associated with an atom of carbon, should permeate the membrane more speedily than an isolated atom of oxygen.

5161. It also appears from experiments made by Dr. Mitchell, and repeated by myself, that caoutchouc is probably more highly susceptible of electric excitement, than any other organized body; and probably is at least equal in excitability to any inorganic substance.

### *Of Balsams.*

5162. The word balsam has been used to designate native solutions of resinous matter in essential oils, which, like the turpentine of commerce, exude spontaneously from trees or shrubs.

5163. Among these, however, there are some distinguished by the presence of benzoic or cinnamic acid, or both. It is to the balsam of Peru and Tolu that this remark applies particularly (3060). *Styrax* has also been alleged to contain a minute proportion of benzoic acid, but is not included among balsams by Soubieran, and by this author the corresponding French word *baume* is employed to designate artificial compounds of resins with an acid and volatile oil.

5164. According to Fremy, balsam of Peru consists of resinous matter, of cinnamic acid, a liquid essential oil called cinnameine, and a crystallizable oil supposed to be a hydrate of cinnamyle (3058), called metacinnameine.

5165. Balsam of Tolu consists of resin, cinnameine, cinnamic acid, and, perhaps, metacinnameine.

5166. Balsam of copaiva, or copaiva balsam, consists of a volatile oil, and two resins without any acid.

5167. But agreeably to the investigations of Deville, benzoic acid also exists in the two first mentioned balsams, and when the balsam of Tolu is distilled, per se over a naked fire, a volatile oil, and likewise benzoic ether, are obtained. It is suggested that the resin of the balsam is an oxide of this ether.

5168. It appears that, by reaction with caustic potash, cinnameine is resolved into cinnamic and benzoic acid in union with the alkali: an oily substance, little soluble in water, called peruvine, being simultaneously evolved. There is some analogy between this process, with its results, and those of saponification.

5169. By some authors the word balsam is restricted to resiniferous liquids containing benzoic acid. It might be more reasonable to consider an acid of some kind as requisite, yet it is evident that ordinary acceptation does not justify the idea that the presence of an acid is necessary.

### *Of Gum-resins.*

5170. This name is applied to a class of vegetable substances, which consist of a mixture of resin, gum, essential oil, and extractive matter. *Opium, aloes, ammoniac, asafetida, euphorbium, galbanum, gamboge, myrrh, and scammony* come under this head.

5171. As the resin and essential oil require alcohol, the gum and extractive matter water, for solution, proof spirit is the best solvent of the gum-resins.

### *Of Opium.*

5172. This complex substance contains the following proximate principles;—

1. Morphia, in the state of neutral sulphate, and supermeconate.

2. Paramorphia.

3. Pseudomorphia.

4. Codeia, in the state of supermeconate.

5. Narcotina.

6. Narceia.

7. Meconin.

8. Meconic acid, partly combined with bases.

9. Ulmin.
10. A peculiar resin.
11. A fatty oil.
12. Caoutchouc.
13. Gum.
14. Bassorin.
15. Lignin.
16. The sulphate of potash, lime, and magnesia.

5173. Of these substances, *morphia*, *paramorphia*, *pseudomorphia*, *codeia*, *narcotina* and *narceia* are ranked as vegetable alkalies, all having the power of neutralizing acids. *Meconin* is an indifferent or neutral substance, which was announced to exist in opium in 1832, by M. Couerbe, but which is found to be identical with the *crystallizable principle* of M. Dublanc, jun., discovered several years before. *Paramorphia*, *pseudomorphia*, *narceia*, and *meconin*, exist in opium in very small amount. For a method of detecting opium, see meconic acid (5265).

*Of Bitumen, Petroleum, Naphtha, Amber, and Mineral Coal.*

5174. There is in nature a gradation of substances, apparently arising from the wreck of a former world, from naphtha, which is highly volatile, to anthracite, which is extremely insusceptible of the aëriform state. Possibly the diamond may be considered as terminating the series; as it has been suggested to result from the decomposition of vegetable matter.

5175. *Bitumen*, in a concrete state, is exemplified by asphaltum. The coal called bituminous, owes to the presence of bitumen its capability of caking, and yielding carburetted hydrogen when ignited. Bitumen is found also in a tarry state, or more or less liquid, according to the quantity of petroleum with which it may be united. Caking coal may be considered as a compound of carbon with bitumen, and a minute portion of silex and iron, and sulphur: anthracite, as consisting of the same ingredients, substituting water for bitumen, though in a lesser proportion.

5176. *Petroleum*, or naphtha, is the name given to an inflammable liquid which rises out of the earth like spring water, so that some wells cannot be freed from it. The name of naphtha is more properly given to a very volatile oil which may be obtained from petroleum by cautious distillation, preferably with water. Besides more or less bitumen, by which it is discoloured to a greater or less degree; agreeably to the researches of Pelletier and Walter, petroleum comprises three volatile oils, and a species of paraffin. The names, boiling points, and formulæ of the oils, are as follows:—naphthol,  $C^{24}H^{22}$ , boils at  $384^{\circ}$ ; naphthene,  $C^{16}H^{16}$ , boils at  $239^{\circ}$ ; naphtha,  $C^{16}H^{14}$ , boils between  $185^{\circ}$  and  $194^{\circ}$ .

5177. *Naphtha proper*.—The last mentioned oil may be considered as the true naphtha, being the liquid employed for the preservation of the metals of the alkalies. It much resembles oil of turpentine in properties and composition. Potassium, of which the specific gravity is .865, sinks readily in naphtha.

5178. During the destructive distillation of bituminous coal, a bituminous liquid, called coal tar, condenses, from which an artificial naphtha may be extricated, which is used as a solvent of caoutchouc.

5179. *Seneca Oil, American Oil*.—Under these names two liquids are now to be met with in commerce. The former is obtained from the vicinity of the lake after which it is named; the latter from a well in Kentucky, which was sunk for the purpose of obtaining spring water. Either yield, by distillation with water, more or less naphtha, and contain heavier oils requiring a higher heat to bring them over by distillation.

5180. *Amber* is a singular fossil, which is supposed to owe its origin to vegetable matter. It is distinguished by burning with a peculiar odour, and yielding, when subjected to distillation, *succinic acid*, and a peculiar essential oil, called *oil of amber*, which resembles crude naphtha in smell and other properties. The acid sublimes into the neck of the retort in crystals. Amber is insoluble both in water and alcohol. Dr. Kane suggests that it may be the turpentine of an extinct species of tree, belonging to a former geological epoch. It would seem rather to be a variety of copal, which it so much resembles in appearance and properties, as that the one may be mistaken for the other, on superficial examination.

## OF ACIDS.

### *Of Acids relatively to the Proportions of Base required for their Saturation.*

5181. It has long been known, that certain acids, such for instance as nitric, or chloric acid, cannot be isolated so as neither to be in unison with water, nor with any other oxide acting as a base. Until of late, however, it does not seem to have been perceived, that the water in such acids must act as a base. Now it is held, that wherever water, unless replaced by another oxide, cannot be expelled from an acid without a decomposition of the acid, or a destruction of its properties, such water, while combined with the acid, must be considered as acting as a base. Moreover, as when one atom of water, or other oxide, is found indispensable to the existence of an acid, that one atom has been considered as performing a basic part, so, consistently, when two or three atoms of water or other oxide are ascertained to be no less necessary, the two atoms, or three atoms of water or other oxide thus required, are considered as acting as bases. Experience has shown that in this way, some acids require one, others two, and others

three atoms of base, and are called accordingly monobasic, bibasic, or tribasic acids.

5182. But, it may be inquired, how is this diversity of the acids ascertained? The answer is, by ascertaining the loss of weight which they sustain, on combining with a base to saturation. Of course, the weight of the salt formed with a dry base, should be the aggregate weight of that base and the anhydrous acid. This may be found by desiccating the resulting salt. The difference between the weight of this saline aggregate, and that of the sum of the weights of the hydrated acid and dry base, must be due to the escape of basic water.

5183. Although when water, which can be replaced by another base, is essential to the existence of an acid, it follows that it must be considered as basic; the student ought not to infer that it cannot act as a base to an acid which can exist without it. Both sulphuric and phosphoric acid unite with water as a base, although they exist in the anhydrous state. This preliminary explanation having been given, it is hoped that the student will be prepared to understand the following statement, respecting the three classes of acids above mentioned.

5184. Acids, as respects the quantity of base with which they are capable of combining, may be divided into three classes. Those requiring one equivalent of base, called monobasic; those requiring two equivalents, called bibasic; those requiring three equivalents, called tribasic acids. Water acts as a base in combining with any acid of either class, and is subject to the same laws as other bases.

5185. The compounds, hitherto called hydrated acids, are in combination with one, two, or three atoms of basic water, accordingly as they belong to the monobasic, the bibasic or tribasic class.

5186. When the hydrate of an acid of either kind is presented to a base, capable of displacing water, for every atom of the new base which unites with the acid, an atom of water must be expelled. As the single salts of monobasic acids can have only one equivalent of base, so in them there can only be one kind of base; but in bibasic acid salts the equivalents may be of one kind only, or of two kinds; and in tribasic acid salts, of one kind, or of

o, or of three kinds. In either case, water, acting as a base, is liable to be present in the same proportions as any other base, and may replace or be replaced by other bases. All that has been said of water, is also true in many cases of oxide of ammonium.

5187. Different bases, salified by the same monobasic acid, may combine to form double salts. Of course, salts requiring water for their base are not excepted; but double salts thus formed with an equivalent of basic water, on account of their sourness or reaction with litmus, have been called acid salts. When in such salts the water is replaced by another base, two neutral salts result, which may be separated by crystallization, provided they differ in solubility, and crystallize separately, in forms sufficiently different to be distinguished.

5188. When monobasic acids are united to more than one equivalent of base, not being neutral, as bibasic or tribasic acids are, with the same number of basic equivalents, they are called basic salts; which conveys the idea of a salt consisting of an acid united to one or more atoms of base in excess. Yet when the atoms thus situated, are presented to another atom of the same monobasic acid, in the state of hydrate, they can displace no more than one atom of basic water; for this obvious reason, that there can be no more than one atom of basic water in union with such an acid.

5189. Salts of bibasic acids, when one of their atoms of base is water, are, from their sourness, called acid salts; but, substituting another base for water, does not produce a double salt. For this, two atoms of acid and four atoms of base would be requisite.

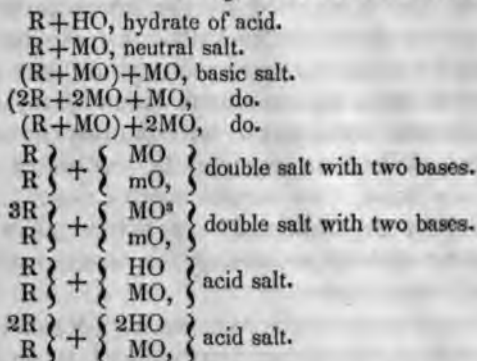
5190. Acids produced by dry distillation, are called pyrogenic acids. Such acids are rarely created by subjecting monobasic acids to that process; but pyrogenic acids, when thus created, are always monobasic.

5191. Under like circumstances, bibasic acids give birth to two new monobasic acids, as in the instance of lactic acid.

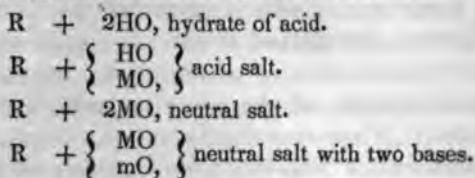
5192. By the same process, tribasic acid may give rise to three equivalents of a monobasic acid, as in the case of uric acid; or they may be resolved into two monobasic acids, or a bibasic and a monobasic acid, as may be seen in the case of meconic acid.

5193. In the following table, taken from Gregory's big, the anhydrous acid is represented by R, the metoxybase by MO, and water by the usual symbol HO.

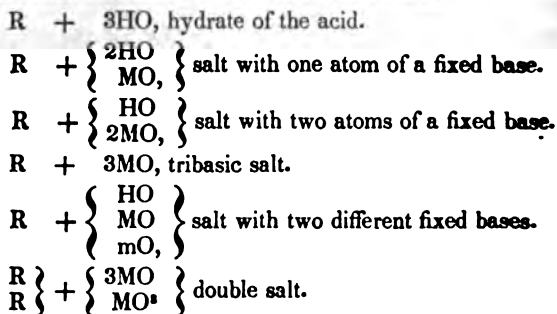
*Formula for Monobasic Salts.*



General formulæ for the salts of the bibasic acids.



General formulæ for the salts of the tribasic acids.



*Of Acetic Acid.*

5194. Acetic acid is monobasic, being a hydrated t ide of acetyl (3093), as may be seen from its form  $C^4 H^3 O^3 + HO$ .

5195. As the cause of the sourness in fermented liqu and various products of vegetation, this acid, having



the first to attract human observation, has given a name to the whole class of acids; though at this time many of the compounds recognised as acids, are devoid of the attribute on which the general name is founded. Acetic acid is the only valuable ingredient in vinegar, causing the sourness indicated by its name, which differs but little from *aigre*, the words expressive of sour wine in French.

5196. This acid occurs in nature in many products of the vegetable and animal organization: as for instance, in the black elder (*sumbucus niger*); the pleurix dactilifera, and rhus tiphinus; in sweat, urine, milk, and the fluids of the stomach.

5197. It had long been observed that the fermented liquors containing the most spirit made the strongest vinegars. Although pure alcohol is not liable to be acidified *per se*, when diluted with water holding fermentable substances, it is readily converted into vinegar. For this purpose each atom requires four of oxygen. Two atoms of this element are requisite to remove two of hydrogen, by which ethyl (3069), the radical of the alcohol, is changed into acetyl (3093), the radical of acetic acid. At the same time, two atoms of oxygen are required to be added to the one atom previously in union with the ethyl, to make the three required for acetic acid, which is a trioxide of acetyl. The formula of alcohol is  $C^4 H^5 O + HO$ . If to this we add four atoms of oxygen, we have  $C^4 H^5 O^5 + HO$ , which gives the formula of hydrated acetic acid  $= C^4 H^3 O^3 HO + 2HO$  in excess.\* See paragraph 3094 and note.

5198. I shall defer the exposition of the phenomena, causes, and circumstances, on which the conversion of various liquids into vinegar is dependent, until I treat of fermentation. Practically, every body has a general idea of the mode in which *wine*, *cider*, or *beer*, vinegar, is obtained.

5199. Acetic acid is also a product of the destructive distillation of wood. In that case it forms what has been

\* Liebig alleges that a strong and agreeable vinegar may be made by exposing to the air for some weeks in a warm situation, the following mixture;—100 parts water, 13 brandy, 4 parts honey, and 1 crude tartar. Of course, one part cream of tartar might be substituted for the crude tartar.

The acetification of mixtures of vegetable juices with spirit, has been very much expedited, of late years, by a high temperature, and allowing the liquor to drop from tubes through holes like those of a colander, on beach wood shavings. Respecting this, and other processes for the generation of acetic acid, much information will be found in Ure's Dictionary of Arts and Manufactures; also in Liebig's *Traité de Chimie Organique*, 386.

called pyroligneous acid, which contains various other substances. From these the acid is extricated by combining it with a base, and subsequent distillatory decomposition of the resulting salt by sulphuric acid, the impure acetate having been first cautiously fused to get rid of impurities.

5200. The acetic acid, thus obtained, is much diluted with water, from which it may be freed by digestion with anhydrous sulphate of soda, and subsequent distillation. In this way, according to Liebig, a sufficient degree of concentration may be attained to render the acid crystallizable. As in the case of other organic acids, that in question cannot exist excepting in combination with basic water, or some other base.

5201. The distillation of dry acetate of copper, has been long made the means of evolving the contained acid, in a concentrated state. Resort has also been had to the decomposition of the dry acetate of soda, or lead, with equivalent portions of concentrated sulphuric acid. 1. According to Liebig, the proportions should be, 3 acetate of soda, with 9.7 acid: or, 3 acetate of lead, with 8 acid.

5202. Pure hydrated acetic acid crystallizes in shining, transparent lamellar, or tabular, crystals. At the temperature of  $63^{\circ}$  nearly, these crystals fuse into a limpid liquid, of the density of 1.063; of which the pungent and distinguishing smell and taste may be inferred, from the inferior effect of strong vinegar. In its concentrated form, as it is capable of blistering the skin, its action upon the tongue must be insupportable. Like other liquids greedy of water, it produces fumes on contact with the aqueous vapour of the atmosphere. It boils at  $142^{\circ}$ , and unites in all proportions with water, alcohol, ether, many essential oils, camphor, and some resins. When in the state of vapour, it is capable of burning with a blue flame, and being resolved into water and carbonic acid.

5203. It has been mentioned, that, when liquid, crystallizable acetic acid is denser than water. To a certain extent, by admixture with this liquid, a condensation ensues; but a further addition of water causes the opposite change. Equal parts by weight have the same density as the pure hydrate. The highest density attainable is 107, indicating the presence of three atoms of water, and one of anhydrous acid; or by weight, 772 acid, and 228 water.

5204. Allusion has been made to the process by which platinum black causes the acetification of alcohol\* (1607).

5205. *Of Pyroligneous Acid.* The process by which charcoal is obtained by the destructive distillation of wood, has been mentioned as one by which acetic acid is generated. Thus produced, it is generally known as pyroligneous acid, being very much disguised by impurities. In fact, pyroligneous acid so called, contains beside the acetic acid, paraffine, eupione, kreosote, and the pyrogene, resinous matter, called pyretene by Berzelius.

5206. When the process is performed with a suitable apparatus, this acid is collected. Pyroligneous acid may be considered as the matter of wood smoke in the liquid form; and when applied in this state to salted meat, is at least as efficacious as when employed as smoke in the usual way. The process of the smoke-house is less susceptible of precision, and is liable to produce an injurious rise of temperature.

5207. *Of the Acetates.*—These salts are soluble, with very few exceptions. Only two are cited as insoluble by Liebig; those of molybdenum and tungsten. The acetates of silver and of the protoxide of mercury, are soluble only to a very small extent. All the acetates smell of acetic acid, on the affusion of sulphuric acid. Those formed with oxides of the metals proper, yield their acid on the application of heat, with a partial decomposition. When the base is a fixed alkali or alkaline earth, they are resolved into carbonates and acetone (3098).

5208. When in diluted aqueous solution, especially when the base is in excess, any alkaline acetate undergoes a partial resolution into a carbonate.

5209. Of course, any of the acetates may be formed by the saturation of the acid with the proper base. In some cases, they may be obtained advantageously by double de-

\* Dr. Ure alleges, that by means of twenty to thirty pounds of platinum powder, which does not waste, we may transform, daily, three hundred pounds of bad spirits into the finest vinegar.

For this purpose, platinum black may be made, by fusing platina ore with twice its weight of zinc; pulverizing the resulting alloy, and subjecting it successively to diluted sulphuric and diluted nitric acid, the latter with heat. The zinc being dissolved or oxidized, the residual powder, after washing with a solution of potash and water, is fit for the purpose in question.

The process has been conducted in a wooden box having a capacity of twelve cubic feet.

composition, as illustrated in the case of sulphate of zinc, and acetate of lead, which when added together in a state of solution, form sulphate of lead and acetate of zinc. Formerly, the acetate of potash was known as foliated earth of tartar, acetate of ammonia as spirit of mindererus.

5210. *Of Acetate of Ammonia, or Spirit of Mindererus.* This salt may be obtained by distilling sal ammoniac with acetate of soda, when, after the escape of some ammonia, the acetate comes over liquefied, and crystallizes in transparent, colourless needles.

5211. This acetate has an acid reaction, is deliquescent, and soluble in all proportions in water and alcohol. Of the acetates of lead some mention has already been made. (1740.)

5212. Sugar of lead, according to Liebig, contains an equal number of atoms of acid and base. Besides this, there is *sesquibasic acetate*, consisting of two atoms of acid, with three atoms of base.

5213. *Tribasic acetate*, consisting of one atom of acid, with three atoms of base.

5214. *Sesbasic acetate*, holding one atom of acid to six atoms of base. Sugar of lead is, of course, the neutral acetate.

### *Of Lactic Acid.*

5215. This acid is that which exists in sour milk, whence its name from lac, the latin for milk. It has lately been shown to be generally the product of a peculiar fermentation, called viscus, to which the juices of plants, containing albumen, are spontaneously liable, when yeast is not added, at a temperature between  $86^{\circ}$  and  $104^{\circ}$ . This fermentation differs from the vinous, in being accompanied by the evolution of inflammable gases, as well as carbonic acid, and in not being productive of alcohol, but of lactic acid and manna sugar, or mannite (4074). It is obtained from sour milk by saturation with soda, and decomposing the resulting lactate by sulphuric acid. By a previous addition of lacticin, in the ratio of eight ounces to eight pints of the milk, the quantity of acid produced may be advantageously increased.

5216. Lactic acid is monobasic, and as it exists in the anhydrous salt which it forms with zinc, consists of  $C^3H^3O^3$ .

Its composition is remarkable, since, as the hydrogen and oxygen which it contains exist in the proportion for forming water, it might be represented as a hydrate of carbon; a composition which usually belongs to bodies, which, as it respects basic and acid properties, act indifferently. When in its most concentrated form, it appears as a sour syrup, incapable of crystallization. On being heated to  $482^{\circ}$ , it is decomposed, yielding, among other products, a large amount of a crystallized acid sublimate. As this consists of  $C^6 H^4 O^4$ , it was for some time treated as anhydrous lactic acid; but as the anhydrous lactate of zinc is said to contain  $H^5 O^5$ , this sublimate must be regarded as a distinct acid. By boiling in water, the new acid combines with an atom of oxygen and an atom of hydrogen, and is consequently reconverted into lactic acid.

### *Of Citric and Malic Acid.*

5217. The name of citric acid indicates its origin.\* It exists in the lime and lemon, in union with mucilage and malic acid. Its combination with mucilage is so intimate as to render it impossible to separate the acid without first uniting it with some other matter. Alcohol combines with the acid, and precipitates the mucilage. Yet, the alcoholic solution, thus obtained, does not yield crystals, even after evaporation, re-solution in water, and evaporating the water.

5218. The most efficient mode of obtaining this acid pure, is to saturate the juice of lemons with chalk or whiting, and afterwards to decompose the citrate of lime thus formed, by sulphuric acid, duly diluted. The citric acid may be obtained in crystals, from the supernatant liquid, by evaporation.

5219. Citric acid is crystallizable. Its taste is intensely acid when concentrated, but agreeably sour when dilute.

5220. It is a tribasic acid; its formula, when dried at  $212^{\circ}$ , being represented by  $C^{12} H^3 O^{11} + 3HO$ . The atoms of water are essential to the composition of the acid in its free state, and cannot be removed unless by substitution of an equivalent number of atoms of some other base.

5221. Malic acid derives its name from the apple, as

\* From the fruit of the genus citrus, including the orange, citron, lemon, lime, and shaddock.

in this fruit it predominates, as well as in gooseberries, currants, and other similar fruits. It may be had pure by saturating lime with apple juice, and decomposing the malate of lime by sulphuric acid.

5222. Professor Wm. Rogers, of the University of Virginia, has ascertained that this acid abounds in different species of sumach, in the state of bimalate of lime. Malic acid is bibasic, its formula being  $C^5 H^4 O^8 + 2HO$ .

5223. Malic and citric acids afford very good examples of the operation of a law, to which a great many of the vegetable acids are subjected. At a temperature a little above that at which they melt, they severally yield new acids. That yielded by citric acid, is identical with the acid found in the *aconitum napellus*, and also the various species of *equisitum*. Hence, it has received the name of aconitic or equisitic acid. Whether obtained from citric acid by heat, or from either of its other sources, it exists in the form of white crystals, soluble in water, and sour in taste. The acid into which malic acid is changed, under similar circumstances, is also found in nature in the Iceland moss, and in the *fumaria officinalis*. Hence it has been called fumaric acid, although Pelouze, who first obtained it from malic acid by heat, called it paramalic acid. Both of these acids differ from the citric and malic acid, from which they are produced, only in having lost the elements of two atoms of water.

5224. When either of the acids thus obtained, by heating citric or malic acid, is exposed to a higher temperature, a further change takes place, and volatile acids are formed, fumaric acid yielding malic, and aconitic producing itaconic acid. The former would seem to be formed by a mere transposition of the elements of water present, which appear as two atoms of water of crystallization, instead of entering as before as two basic atoms into the integral composition of the acid. A farther application of heat converts itaconic into citraconic acid; while malleic acid, if kept in a state of fusion for a length of time, reverts to the condition of fumaric acid.

5225. It must be observed, that if citric or malic acid be heated, without keeping them at the temperatures necessary for the formation of the acid compounds which they respectively produce, the result will be a mixture in the one case of fumaric acid and malic acid, in the other, of aconitic, itaconic and citraconic acids.

### *Of Tartaric Acid, and Paratartaric or Racemic Acid.*

5226. Tartaric acid is found in many vegetables. It is named from tartar, an appellation given to a deposition from wine, which contains this acid united with potash and water. This tartrate, when freed from impurities, is known officinally under the name of cream of tartar. When to twenty-four parts of this salt, thirteen of carbonate of soda are added, sal Rochelle, a tartrate of potash and soda, is produced; and in like manner, tartar emetic, by replacing the basic water by the sesquioxide of antimony. Another pharmaceutical compound, called tartarized iron, is pre-

ced by replacing the water of cream of tartar by iron, which is taken up in the state of protoxide, but becomes, on exposure, more or less sesquioxidized.

5227. Tartaric acid is procured from cream of tartar in the crystals, by adding chalk until effervescence ceases, and decomposing the precipitate by diluted sulphuric acid. The neutral tartrate of potash left, may be decomposed by quicklime or chloride of calcium, and the resulting tartrate of lime will yield the acid in the same way as the analogous tartrate, obtained in the first instance by the addition of chalk.

5228. Tartaric acid is extremely sour, and reddens litmus. It is bibasic, its formula being  $C^8 H^4 O^{10} + 2HO$ . In consequence of this bibasic character, the salts which it forms with one atom of a fixed base are sour, have an acid reaction, and require the presence of an atom of basic water. Thus the salt heretofore described as the bitartrate of potash, must now be considered as the tartrate of potash and water, since it consists of one atom of tartaric acid, one atom of potash, and an atom of basic water.

5229. *Of Paratartaric or Racemic Acid.*—A manufacturer of Thann, in Germany, in preparing tartaric acid from cream of tartar, which had been deposited from the mine of that country, discovered an acid differing from tartaric which it was his object to procure, and which he supposed to be the oxalic. Gay-Lussac subsequently proved, that while possessed of peculiar qualities, its equivalent was the same as that of tartaric acid. By Berzelius it was afterwards shown to be isomeric with this last mentioned acid, and he has consequently named it paratartaric acid. The appellation of racemic, has also been applied to it. Paratartaric acid crystallizes in a different form from tartaric acid proper. It is likewise less soluble.

5230. The action of heat on tartaric acid is strikingly peculiar. At a temperature merely sufficient to produce fusion, two atoms of the acid give off one of the four atoms of the basic water combined with them, losing at the same time one fourth of their saturating power, and causing the acid to become sesquibasic, so that two atoms of it saturate only three of base. The name of *tartralic* has been applied to the acid in this state.

5231. A still further application of heat removes another half atom of water and produces tartrelic acid, which is *monobasic*, saturating only one atom of base, and requiring in the free state the presence of but one atom of water. A still higher temperature removes all basic water, and leaves a brown white mass, insoluble in water, and hence no longer sour or capable

of reddening litmus. The composition of this body is  $C^6 H^4 O^{10}$ . Consequently, it is identical with that of tartaric acid freed from its basic water, as it exists for instance in the bibasic tartrate of lead. If left long in contact with the water, this insoluble compound gradually takes up two atoms of the oxide of hydrogen, and becomes the ordinary soluble bibasic tartaric acid. It has been considered, that the absence of sourness, in this only instance of an isolated anhydrous organic acid, is favourable to the idea that oxacids are hydrurets of compound radicals owing their acid reaction to hydrogen; but it should be recollected, that the absence of this action is an invariable consequence of insolubility. No insoluble hydruret of which there are instances among the oils or etherial compounds is sour. Nor is it that portion of water which enters the tartaric acid as a base, and on the hydrogen of which the hypothesis relies, which confers either sourness or the capacity for acid reaction with vegetable colours. Independently of moisture, the gaseous hydracids, erroneously so called, have, I believe, no such properties.

5232. *Of Liquid and Solid Pyrotartaric Acid.*—By destructive distillation, tartaric acid yields two acids, to which the preceding appellations have been given. Liquid pyrotartaric acid forms a monobasic ether, and various salts. Its formula is  $C^6 H^4 O^5$ . Solid pyrotartaric acid is generated in small proportion, during the destructive distillation of tartaric acid; but is yielded more copiously by subjecting cream of tartar to that process. Graham, 948.

#### *Of Guaiacine, or Guaiacinic Acid.*

5233. In the *Journal de Pharmacie*, for 1842, p. 386, notice is given by J. Pelletier, of the results of an investigation, which, though it had not been completed, enabled him to allege that the peculiar principle of gum guaiacum, which he calls guayacine, in English guaiacine, may be isolated by either of two processes. According to one, an alcoholic solution of acetate of lead is to be added in successive portions to a tincture of the resin, rejecting the latter portions of the precipitates formed. The compound thus procured, is to be well washed with water first, and afterwards with alcohol. Then being suspended in water, is to be exposed to sulphydric acid, by which the lead is precipitated as a sulphide. The guaiacine is then taken up by alcohol.

5234. According to the other process, hydrate of lime is added to the tincture, by which means a compound, of the guaiacine and lime, is obtained. From this the guaiacine may be easily extricated.

5235. Guaiacine has, in a high degree, the property of becoming blue by absorbing oxygen, and, after being thus coloured, may be restored to its previous state by substances greedy of oxygen, such as sulphydric or sulphurous acid, protoxide of iron, or protochloride of tin. Re-exposure to the air restores the blue colour.

5236. Moist chlorine, or an aqueous solution of this gas, turns guaiacine blue; but an excess renders it green, and yellow, successively. From the last mentioned state it cannot be restored, having undergone a chemical change.

5237. Notwithstanding the property of combining with bases, Mr. Pelletier hesitated to designate it as an acid, but in this, as it was found to combine with bases, I consider him as misjudging. The analogy between this resin and indigo, as respects changes of colour, must strike every one acquainted with the facts.



5238. I presume in English the principle which he has isolated, will be called guaicine; or if it be an acid, as from the account given, it evidently ought to be considered, the name will be guaiecinic acid.

### *Of Tannic Acid.*

5239. From its formula,  $C^{18} H^5 O^9 + 3HO$ , it may be seen that the tannic acid is tribasic.

5240. The art of converting the hides or skins of animals into leather, by soaking them in infusions of the bark of oak and other trees, had long been practised. Subsequently it was ascertained that this change arose from a chemical combination ensuing between the gelatin of the skin or hide, and a vegetable principle called tannin, from its efficiency in the process of tanning abovementioned. Berzelius first treated of tannin as an acid. This view being adopted, the principle is now universally designated as tannic acid. It is peculiarly abundant in oak galls, giving to an infusion of them the property of causing, with iron, a black colour, whence its use as an ingredient of common writing ink.

5241. Tannic acid is likewise found in a great number of vegetables, generally in their bark or roots, but not unequally in their leaves and seeds, and even in their flowers and fruits, before they have reached maturity. It is, in fact, the most frequent cause of astringency in vegetable products.

5242. It may be procured, according to Mr. Pelouze, in state of purity, by introducing powdered galls into a vessel, with a body and pipe resembling that of a funnel, but contracted above into a neck like that of a bottle. The top of this vessel should be furnished with a cock, and must be made to descend into a tincture bottle through the mouth. The galls are then to be covered with sulphuric ether, of the officinal strength, and the mouth of the vessel being corked, they are to be left in contact with the ether for several hours. The liquid being then allowed to ascend into the bottle, will be found to separate into two portions, of which the heaviest is a solution of tannic acid. From this solution the acid may be obtained in the solid form by washing with ether, and evaporation, in vacuo, over sulphuric acid. Thus obtained, it is inodorous, astringent, yellowish white, and somewhat crystalline.

5243. The oxides of the following metals form insoluble

tannates, and hence yield precipitates with tannic acid, or an infusion of galls. The colours of these precipitates are as follows:—

The precipitate formed with lead or antimony, white.

With tin, nickel, cobalt, silver, various shades of yellow.

With tantalum or bismuth, orange.

With titanium, blood red.

With platinum, green.

With chrome, molybdenum, uranium, and gold, brown.

With osmium and sesquioxide of iron, deep purple, like or ink colour.

5244. On account of the insolubility of the tannate of antimony, an infusion of galls, or of oak bark, is an antidote for tartar emetic and other antimonial preparations.

5245. Tannic acid has also been found a test for, and precipitant of, the organic alkalies, and must be none the less an antidote for their poisonous influence.

5246. The aqueous solution of tannic acid reddens litmus. It does not affect solutions of the protoxide of iron, and the intense colour produced as abovementioned, with the sesquioxide, may be removed by reagents, which reduce the iron to the state of protoxide, as already stated (1817).

5247. Ink is best made with the green sulphate of iron, because, so long as the iron is not sesquioxidized, remaining in solution, it can penetrate the paper better; and it soon peroxidizes, and consequently blackens, by exposure to the atmospheric oxygen. (Ure.)

5248. By a piece of raw hide, pure tannic acid may, in a few hours, be taken up from a solution so completely, that if no gallic acid be present, the liquid will not be affected by a solution of sesquioxide of iron.

5249. According to Graham, tannic acid precipitates a solution of starch and albumen, and is capable of combining with animal fibrin.

5250. *Of Artificial Tannin.*—A substance resembling tannic acid in many of its properties, and called, generally, artificial tannin, is formed during the action of nitric or sulphuric acid on a great variety of vegetable substances. One variety of this tannin is formed by the reaction of nitric acid with charcoal.

*Of Gallic Acid.*

1. Formula of the dry acid,  $C^7 H O^3 2HO$ . When  
lized, one additional atom of water is present.

2. This acid and tannic acid appear to be almost  
more or less associated; so that they are generally  
resent, where either is found. This is now explained  
fact, that tannic acid is liable to be converted into  
acid spontaneously.

3. Agreeably to one of the processes recommended  
curing the last mentioned acid, nut galls, made into  
e with water, are to be exposed to the air for seven  
eks at the temperature of  $80^\circ$  nearly, water being  
ed so as to compensate for evaporation. The re-  
mass is to be subjected to boiling water, and the  
n thus obtained being filtered, the gallic acid sepa-  
n the crystalline form. It is rendered quite pure by  
tion, digestion with animal charcoal, and re-crystal-  
l.

4. If the precipitate, obtained by adding sulphuric  
a concentrated extract of galls, be washed with a  
quantity of water, and then dissolved by gradually  
it to a boiling solution of one part of sulphuric acid  
of water, gallic acid is generated, and, by refrige-  
separates from the liquid in crystals. The impure  
us isolated, may be purified partially by re-solution  
ystallization; or more thoroughly by adding to a  
n of it acetate of lead, and decomposing the result-  
oluble gallate of the protoxide of lead, by sulphydric  
399). By these means the lead is converted into a  
le, which separates this metal, and much colouring  
, simultaneously; the acid remaining dissolved.  
n, 941.

5. Again, if tannic acid be subjected, for a few mi-  
to a solution of caustic potash, on the addition of  
ric acid in excess, crystals of gallic acid will be co-  
formed on the cooling of the liquid. Kane, 1010.

6. Gallic acid crystallizes from a hot solution in thin  
eedles, which, for solution, require 100 parts of cold  
although, when boiling, three parts are sufficient.  
ery soluble in alcohol, and sparingly soluble in ether.  
gh it is productive of the same changes in solutions

of sesquioxide of iron as tannic acid, it differs from it, not causing any precipitate in solutions of gelatine.

5257. It would appear doubtful whether this acid is ready formed in nature, or whether it be not always a product of the oxidation, or partial decomposition of tannic acid. It has been stated, that the exposure of the acid to the air, or boiling it with an excess of alkali, in the presence of the atmosphere, produces this change, and that it may also be effected by means of sulphuric acid.

5258. On the one hand it has been observed, that the atoms of tannic acid contain the elements of six atoms of gallic acid, and one of grape sugar; and on the other, that the absorption of eight atoms of oxygen would convert an atom of tannic acid into four atoms of carbonic acid and two of crystallized gallic acid. As, according to Braconnot, alcohol and carbonic acid have been evolved from nut-galls during their fermentation, it seems possible that tannic acid may be produced, according to circumstances, either by fermentation, or by the oxidation of the principles present in nut-galls. Indeed, tannic acid itself may appear, from the nature of the sources from which it is obtained, to be, in many instances, the result of a gradual decay of other principles in plants; and when gallic acid, either in its free state, or as it exists in the gallates, is exposed to the air, it undergoes a still further change into carbonic acid, and a brown vegetable substance. Hence it may be conjectured, that both of the acids in question are the products of different stages of one continued transformation.

5259. If gallic acid be heated to about  $400^{\circ}$ , it is decomposed into carbonic acid, and a new acid which sublimes in brilliant white plates. This acid has received the name of pyrogallic, and is soluble in water, alcohol, and ether. If, on the contrary, the heat be raised above  $450^{\circ}$ , an insoluble black mass remains in the retort, to which, from its combining with alkalis, and its colour, the name of melangallic acid has been given. These results are only worthy of notice as forming part of a series of transformations which most of the organic acids undergo through the application of heat.

5260. An acid, called the elagic, is frequently produced during the exposure of galls to the air, which gives rise to the formation of gallic acid. There are several species of vegetable products in which acids, resembling the gallic and tannic acids, though not identical with them, have been discovered. Thus, in the bark of the various species of cinchona, combined with quinia or cinchona, are found two acids, the cinchonic and cinchon-

nic, whose physical properties stand in very nearly the same relation to each other as that borne by gallic and tannic acid; and in catechu, an extract obtained from the mimosa catechu, there have been discovered two acids, the catechuic and the catechutannic, of which nearly the same statement may be made. It does not appear, however, that in either case one has the property of being converted into the other, as is the case with tannic and gallic acids. Berzelius, however, is of the opinion, that all forms of tannic acid found in plants are identical in composition, but modified by association with other matter.

### *Of Meconic Acid.*

5261. Formula,  $C^{14}HO^{11} + 3HO$ ; when crystallized  $+ 6HO$ . Meconic acid is tribasic.

5262. When a solution of acetate of lead is added to an infusion of opium, a precipitate is obtained, consisting of acetate of lead. From this the lead may be precipitated as a sulphide by means of sulphydric acid, and a solution of the liberated meconic acid obtained by filtration. This acid exists in opium, combined with morphia and codeia.

5263. With solutions of the sesquioxide of iron, meconic acid produces an intense red colour; with protoxide of lead an insoluble precipitate. It is to this affinity, for oxidized iron, that we owe the process, above described, for producing this acid.

5264. Meconic acid produces a taste, at first sour, and subsequently bitter, and reddens litmus paper. Being a basic acid, it forms three classes of salts, in which the water present may be replaced, partially or entirely, by one, two, or three atoms of base. Like other organic acids which have been described, meconic acid is converted by heat into another acid, the *komenic*, carbonic acid being evolved; and as this komenic acid cannot be volatilized, it is at a higher temperature, converted into pyromeconic acid, which may be sublimed without further change. Each of these transformations is accompanied by the loss of an atom of basic water, and a diminished capacity of neutralizing bases.

### *Of a Method of detecting the Presence of Opium.*

5265. The property which meconic acid has of precipitating with lead, and of producing a red colour with iron, may enable us to detect opium, when present in a very small quantity in solution.

5266. If ten drops of the tincture of opium, commonly called laudanum, be mingled with half a gallon of water, on adding a few drops of the acetate of lead, there will be a precipitation which, at the end of a few hours, will be perceptible in flocks. These flocks may be accelerated by detaching gently from the sides of the recipient with a glass rod. The vessel should be covered so as to concentrate them during their descent. After they are collected at the bottom of the vessel, about 50 drops of the red sulphate of iron, and an equivalent portion of sulphuric acid should be introduced among them by means of a small glass tube. The presence of the meconic acid will be rendered evident by the redness which ensues.

5267. When a red colour is produced by the means here described, it is probable that opium is present; as meconic acid is found only in that drug, and having no anesthetic qualities, is not used separately from it in any pharmaceutical preparation.

5268. It may be proper to mention, that sulphocyanhydric acid produces, with the sesquioxide of iron, a colour resembling that produced by meconic acid.

#### *Of the Acids formed from Sugar.*

5269. Cane sugar may be made to combine, as sugar, with the alkaline earths, and with some of the metallic oxides, though not with the alkalies. In these compounds the sugar exists unchanged, but united to the base by an affinity so feeble, that it may be displaced by carbonic acid.

5270. Nevertheless, if sugar be kept a long time dissolved in an alkaline solution, it undergoes a transformation into a real acid, the glucic acid, which has a sour taste when free, and combines with bases to form salts. In this acid, as in lactic acid, the oxygen and hydrogen are present in the proportion for forming water; and the only change which sugar experiences by conversion into glucic acid, is the loss of several atoms of water. The formula for glucic acid would appear to be  $C^{12} H^8 O^8$ .

5271. If heat be applied to a solution of sugar with an alkaline base, melassic acid is produced either from the sugar directly, or from the glucic acid. It is said to consist of  $C^{24} H^{12} O^{10}$ , so that in forming it, sugar parts not only with water, but also with oxygen.

5272. By the reaction of diluted nitric acid with sugar, a crystallizable acid of a strong sour taste is produced. It was at first supposed to be malic acid, but was afterwards distinguished by the name of oxalhydric. It is now called saccharic acid. Its formula is  $C^{12} H^8 O^{14} 5HO$ . The five atoms of water are essential to the composition of the acid in what is called the free state. When it is united to other bases, the water is replaced, wholly or in part, by a corresponding number of atoms of base. The anhydrous salt which it forms with lead, consists of  $C^{12} H^8 O^{11} + 5PbO$ :

d by its union with the oxide of that metal, it forms three other salts, in which we find  $C^{12}H^3O^{11}$  combined, respectively, with  $3PbO + 2HO$ ,  $2PbO + 3HO$ , and  $PbO + 4HO$ . These facts respecting the composition of the ccharates are instructive, as furnishing support to the theory of poly-acids; since, if we do not have recourse to that theory, we must suppose the existence of a distinct acid in each of the salts above mentioned, and that one of them has the property of combining with five atoms of base, and not with any smaller quantity.

5273. When lactic (sugar of milk, 4070) is subjected to the action of luted nitric acid, mucic acid is produced. It may also be obtained by substituting gum, or mannite, for the sugar of milk. It exists as a crystalline powder of difficult solubility, and a feebly acid taste. Its formula is  $C^{12}H^3O^{14} + 2HO$ .

### *Of Formic Acid.*

5274. It is inferred, that between formic acid, formyl (4019), and methyl (4016), the same relation exists as between acetic acid, acetyl, and ethyl; and also that the part performed by alcohol, the hydrated oxide of ethyl, in the one case, is performed by pyroxylic spirit, the hydrated oxide of methyl in the other. Either the methylic, or ethylic alcohol, by losing two atoms of hydrogen, and acquiring two of oxygen, are converted, the one into acetic, the other into formic acid. Moreover, the same catalytic agent, platinum sponge, or black, may in either case be competent to induce the requisite reaction with atmospheric oxygen. The features which are wanting to complete the resemblance, are congeners severally of aldehyde,  $C^4H^3O + HO$ , and acetous acid,  $C^4H^3O^2 + HO$ . To correspond with these compounds, no hydrated oxide of formyl, nor formous acid, are known.

5275. To render this statement more intelligible, the following formulæ are subjoined. Methyl,  $C^2H^3$ ; formyl,  $C^2H$ ; anhydrous formic acid,  $C^2HO^2$ . To form the hydrated acid, one atom of water,  $HO$ , must be added.

5276. Formic acid was originally obtained from ants. It appears to exist in them naturally.

5277. This acid may be obtained by adding to one part of sugar in an alembic, three parts of well pulverized peroxide of manganese, and three parts of sulphuric acid diluted with its weight of water. The acid should be added in three successive portions. At first, the effervescence is so great as to require the vessel to have fifteen times the capacity which would be necessary to contain the material when quiescent. The formic acid associated

with formic ether, is brought over by distillation. It may be saturated with chalk or an alkali, and the resulting formiate decomposed and isolated by distillation with ten parts by weight of sulphuric acid, diluted with four parts of water.

5278. According to the late Professor Emmet, the presence of peroxide of manganese in this process is unnecessary. Agreeably to his observations, the conversion of many vegetable substances into formic acid, among which maize, may be effected by any of those agents which would effect the evolution of ether from alcohol.

5279. From the investigations of Dobereiner, it appears that formic acid is an excellent reagent for separating the noble metals from solutions in which they are intermingled with other metals proper. If a solution containing one or more noble metals, be elevated nearly to the temperature of ebullition, on adding an alkaline formiate the noble metals will be immediately and entirely precipitated in a very minute state of division. At the same time, by ascertaining the weight of the gas simultaneously evolved, that of the metal thrown down may be determined.

5280. From its solution in water, the bichloride of mercury is converted into calomel with so much facility, and in a state of division so perfect, by formic acid or formiate of soda, that their employment in the preparation of that protochloride was suggested by Dobereiner.

5281. If the same quantity of sulphuric acid and manganese be mingled with six parts of alcohol, the process being, in other respects, the same as that for formic acid above described, formic ether becomes the predominant product. It is freed from formic acid by magnesia, from alcohol by a small quantity of water, and from water by chloride of calcium. By a more extensive contact with water, formic ether is decomposed, and alcohol and formic acid are generated.

5282. Formic acid has a pungent taste, and a peculiar sharp odour. It is more energetic in its affinities than acetic acid. The formiates, like the acetates, are generally very soluble.



*Of Valerianic Acid,  $C^{10} H^9 O^3 + HO$ .*

5283. This acid was described in the last edition of this Compendium, as a product yielded by the root of valerian, (*valeriana officinalis*), when subjected to distillation with water. Since that time, it has been found to be producible, artificially, from a totally different source. It has been discovered by Cahours, that if oil of potato spirit (hydrated oxide of amyl, 123), be allowed to fall in successive drops no faster than it can be imbedded upon platinum black, previously heated, an acid vapour arises from the oxidation of the elements of the oils, which has all the properties of the valerianic acid, obtained from the root of valerian as above mentioned.

5284. During this process, two atoms of hydrogen are replaced by two atoms of oxygen, so that it is quite analogous to the play of affinities by which the acetic and formic acids are generated; the former from alcohol, the latter from pyroxylic spirit.

5285. Valerianic acid is also generated in potato spirit, by the spontaneous absorption of atmospheric oxygen by exposure to the air.

5286. Valerianic acid is a colourless liquid, having an oleaginous consistency, a sharp, acid taste, and a persistent odour, which recalls that of the root of valerian. In the state of protohydrate, according to Graham, it produces a white spot upon the tongue when applied to it. The density of this acid is nearly 937 at 62°. It boils without alteration at 347°, and remains liquid at 5°. When heated in a platinum spoon it takes fire readily, burning with a white flame and much smoke, leaving little residue. It is soluble in eighty times its weight of cold water, and in all proportions of alcohol. It is capable of taking up 20 per cent. of water without losing its oily consistence.

5287. From the formula of this acid it is supposed, that it may consist of a compound radical analogous to acetyl, for which the name valeryl is suggested; formula,  $C^{10} H^9$ .

*Of Caffic Acid and Caffee Tannic Acid.*

5288. According to Kane, the coloured precipitate produced in a decoction of raw coffee, by subacetate of lead, comprises two substances, which may be extracted by impregnation with sulphydric acid while suspended in water, subsequent evaporation of the filtered liquid to the consistence of a syrup, and digestion in strong alcohol. A peculiar kind of tannic acid dissolves, called caffee tannic. A white powder subsides, which, when heated, loses the peculiar smell of roasted coffee. Its solution in water reddens litmus. It is called caffic acid. It is not known whether the tannic acid of tea and coffee are the same.

*Of Acids modified by an Union with Organic Matter.*

5289. Two sets of acids may claim this description. Of these, in one set the organic matter to which the change in them is due, is an oxidized compound organic radical, acting as a base, capable, under favourable circumstances, of being transferred to other acids. In the other set, the matter producing the change does not contain a

compound radical, capable by oxidation of acting as a base, and transferrable to other acids.

*Of Acids modified by Union with an Oxidized Compound Radical.*

5290. Acids of this set, when formed of a monobasic acid, require for existence 1 atom of acid and two atoms of base. One of the acid atoms must be in union with the oxidized radical, the other in union with an atom of basic water, or some other oxide acting as a base. Hence, as already suggested in the case of sulphovinic acid (3086), such compounds may be viewed as double salts of an oxidized radical and oxide of hydrogen, so that, agreeably to the language of Graham, sulphovinic acid is a sulphate of ether and water. But this does not explain the fact, that a *neutral* compound of the acid and oxidized radical cannot be made. Hence, the view presented by the same author, seems to be satisfactory, agreeably to which the two atoms of acid constitute one bibasic acid,\* of course isomeric with that of which it has been formed. This rationale seems to derive strength from the fact, that one atom of tartaric acid in tartrovinic acid, performs the part of two of sulphuric acid in sulphovinic acid, agreeably to the usual idea.

5291. In the other set of *modified acids*, the organic matter does not appear to be in a basic state, not being an oxide of a compound radical, nor capable of separation without decomposition.

5292. In three of the acids belonging to the first set (sulphovinic, phosphovinic, arseniovinic acid), ethyl, being the principal radical, is united to an inorganic acid.

5293. There are other instances, as in that of sulphomethylic acid, in which the oxide of a compound radical plays the same part in combination with a double atom of sulphuric acid, that the oxide of ethyl plays in the three acids above mentioned. Also in tartrovinic, oxalovinic, and camphovinic acid, one atom of tartaric, oxalic, or camphoric acid, performs the office of a double atom of sulphuric, arsenic, or phosphoric acid, in the analogous compounds arising from their association with the same oxidized radical. Other acids exist, having a similar con-

\* Elements, 773.

tution to those last mentioned, and that there will be any more produced hereafter, there is much reason to oppose.

5294. In the second set, there are several which are ascribed to an union of hyposulphuric acid with carbon, hydrogen, and water; as, for instance,

ethionic	{	acid consisting of	}	+ C <sup>4</sup> H <sup>4</sup> O		
hyposulpho-naphthalic					S <sup>2</sup> O <sup>5</sup> hyposulphu-	+ C <sup>20</sup> H <sup>8</sup>
hyposulpho-benzoic						

5295. Other acids consist of the elements of some definite organic compound, such as sugar or indigo, so united to an acid as to form, with bases, crystalline compounds; which, besides the peculiarity of their crystalline form, have a solubility altogether wanting in the salts generated, or else, by the acid with which they are formed. This description is intended for sulpho-saccharic acid, and hyposulpho-indigotic acid; one created by the union of indigo with hyposulphuric acid, the other by the union of sugar with sulphuric acid.

5296. Analogous to the former of these acids, a new acid has been created, by the reaction between sulphuric acid and acetic acid, of which the formula, represented

C<sup>4</sup> H<sup>4</sup> O<sup>3</sup> + S<sup>2</sup> O<sup>5</sup>, makes it a compound of hyposulphurous acid; but Berzelius suggests that the same ultimate elements, in a different order, would give C<sup>4</sup> H<sup>4</sup> O<sup>2</sup> 2SO<sup>3</sup>;<sup>\*</sup> and that the formula thus made out, being divided by two, would give C<sup>2</sup> H<sup>2</sup> O + SO<sup>3</sup>. This would make a sulphated oxide of ethyl, of olefiant gas in other words (095).<sup>†</sup>

*Of Sulphorinic Acid, or the Sulphate of Ether, and Water.*

5297. Of the acids above described, of the first class, I shall here treat sulphovinic acid only. While the limits prescribed to a text-book do not allow me to do more, the importance of this acid, arising from the part which it performs in the production of ethers, and the expediency of selecting it as an exemplification of the set to which it belongs, renders it proper that I should add something to the notice already taken of it under the head of ethyl (3069).

5298. Sulphovinic acid is produced by heating, to the boiling point of the reacting mixture, or about 280°, equal weights of concentrated sulphuric acid and alcohol of from 830° to 850°; or by saturating sulphuric acid with the vapour of ether, and adding water after some hours have elapsed. In

Report on Chemistry for 1841.

It also contains the elements of a hydrated bisulphate of the oxide of acetyl, H<sup>2</sup>O + 2SO<sup>3</sup> + HO.

either case, the resulting liquid is to be saturated with oxide of lead, with lime, or baryta. From the resulting sulphovimates, the sulphovinic acid may be liberated by adding enough acid to saturate the inorganic base; or in the case of that formed with lead, by precipitating this metal by sulphuric acid (899).

5299. It has been mentioned that sulphovinic acid is equivalent to a double sulphate of ether and water; but that the two atoms of sulphuric acid act like one atom of a peculiar bibasic acid, isomeric with sulphuric acid, since it cannot be obtained as a neutral compound, consisting of one atom of oxide of ethyl and one of anhydrous sulphuric acid. The heavy oil of wine, heretofore considered as a neutral hydrated sulphate of etherine, or of the oxide of ethyl, is now viewed as a double sulphate of ether and etherine, or etherole agreeably to a new name employed by Liebig.

5300. Any stronger base presented to sulphovinic acid takes the place of the water, as in other cases where bibasic acids are in union with an atom of water and an atom of another base; but the acid in question differs from other bibasic acids in this, that the oxidized compound radical is essential to the endurance of its bibasic property. As soon as the oxide of ethyl is displaced, the monobasic character of the inorganic acid is resumed.

5301. The salts formed with sulphovinic acid by the replacement of the basic water, have been known as sulphovimates; and so long as the nature of the acid is debateable, it will be preferable to adhere to this name.

5302. One of the most remarkable traits of the sulphovimates, is that solubility which prevents the detection of sulphuric acid, even by solutions of baryta.

5303. In the usual process for producing the organic oxacid acid ethers, by their distillation with alcohol and sulphuric acid, it is probable that the formation of sulphovinic acid is a preliminary effect (3086). But when the mixture is subjected to heat, the organic acid and oxide of ethyl, being competent to form a volatile compound, go off in union, while the affinity between the water and sulphuric acid co-operates to expel them. It is, therefore, a case of double elective affinity, aided by the vaporizing influence of caloric.

5304. It was upon this view of the subject, that Messrs. Boyé and Hare were enabled to foresee the production of the wonderfully explosive perchloric ether, by distilling perchlorate of baryta with the sulphovimate of the same base.

#### *Of Succinic Acid.*

5305. When amber is exposed to heat in an alembic, succinic acid is sublimed in crystals, much contaminated by the essential oil of amber. By digestion in nitric acid, evaporation to dryness, washing in cold water, subsequent solution in boiling water, and finally by crystallization, the acid is obtained pure. When combined with any of the alkalies, it is useful in separating the sesquioxide of iron from the oxide of manganese.

5306. Succinic acid has a sour taste, and reddens litmus paper. The formula of this acid, in the hydrated state, is  $C^4 H^2 O^8 + HO$ , being from the formula monobasic. The formula of the sublimed acid is  $C^4 H^2 O^8$ .

#### *Of Benzoic Acid, $C^{14} H^2 O^8 + HIO$ .*

5307. From the formula it must be evident that this is a monobasic acid, containing one atom of oxygen more than the compound radical, benzole,  $C^{14} H^2 O^8$  (3052): also, that replacing an atom of oxygen by one of hy-

oxygen, must convert it into the hydruret of that radical,  $C^{14} H^5 O^3 + H$  (120). The symbol of this acid is Bz.

5308. Benzoic acid exists ready formed in the resinous product of vegetation improperly called *gum benzoïn*, from which it may be extricated by the following process:—Spread a pound of the benzoïn over the bottom of a flat iron pot, of eight or nine inches in diameter and of about two inches in depth, the mouth of the pot being covered by filtering paper secured to the rim by paste. Thus covered, the pot is to have a canopy of coarse packing paper fitted to it, like a cap, and secured by a bandage of wire. The pot, thus charged and prepared, is to be subjected to a sand bath for three or four hours. Under these circumstances, the cavity, included between the cover and cap, becomes studded with crystals of benzoic acid, quite free from the black empyreumatic oil with which they are liable to be soiled, when sublimed without the interposition of the paper. The acid thus extricated, amounts usually to about four per cent. of the gum employed.

5309. Benzoic acid may likewise be obtained by boiling, in four parts of water, equal parts of gum benzoïn and hydrate of lime, until the liquid is reduced to  $\frac{1}{4}$ th of the original volume. It is in the next place to be filtered, and an addition made of chlorohydric acid. After a second filtration, the acid separates in crystals.

5310. It is presumed that benzoic acid exists in the gum ready formed, and is therefore liable either to be sublimed by heat, or removed by its affinity for lime, from which it is expelled by the chlorine of the chlorohydric acid.\*

5311. *Properties of Benzoic Acid.*—It crystallizes in hexagonal needles, flexible laminae, white, pearly and translucent. When pure it is inodorous, though by being heated, it acquires a smell analogous to that of benzoïn. Although sweet and stimulating to the taste, it irritates the palate when allowed. It reddens litmus feebly, melts at  $248^{\circ}$ , and sublimes at  $293^{\circ}$ , phosphorescing in the dark. It boils at  $492.2$ . Heated in the air it yields a very acrid white vapour, which excites coughing. It is highly inflammable, burning with a very smoky flame, leaving no residue. It is soluble in 100 parts of cold water, and in 25 at the temperature of ebullition; varying with its aqueous solvent when this is distilled from it. For solution one part requires two parts either of ether or alcohol.

5312. Peroxide of iron precipitates in the form of an insoluble subbenzoate, of a reddish white or buff colour, when a soluble benzoate is added to a solution of peroxide of iron, previously neutralized by ammonia without any consequent precipitation. Hence benzoate of ammonia serves to separate the sesquioxide of iron from the oxides of manganese, nickel, or cobalt; when the solution contains neither alumina, yttria, zirconia, nor glucina; of either of which the oxides would be simultaneously precipitated if present. Graham, 851.

#### *Of Hippuric Acid, $C^{13} H^5 N^1 O^5 + HO$ .*

5313. Hippuric acid is found in the urine of herbivorous mammalia. Liebig supposes that it is probably derived from food, in which it pre-exists;

\* M. Jahn has remarked that when the sawdust of guaiacum wood (*lignum vitae*) is treated with a solution of carbonate of soda, sulphuric acid added, the liquid and the resin which precipitates is washed, dried, and subjected to heat in an appropriate apparatus, a small quantity of sublimed benzoic acid is obtained. Berzelius Report, 11, 106. This justifies an inference made by Guibourt, that the crystalline particles observable in the bark of the wood in question, might be benzoic acid.

since it abounds in the urine of horses fed with f                      bles, but in that of the same animals fed with hay, or other dried vegetable matter, is replaced by benzoic acid.

5314. The preparation of hippuric acid is effected by evaporating the fresh urine of the horse or cow, at a temperature carefully kept below that of ebullition, adding sufficient chlorohydric acid to render it perceptibly acid, and subsequently allowing it repose. By these means, impure and coloured hippuric acid separates in crystals. It may be purified by repregnation with chlorine, or by the addition of chlorohydric acid and filtering salt, until the smell and discoloration are removed.

5315. Hippuric acid reddens litmus, crystallizes in large four-sided transparent prisms, susceptible of fusion, without loss of weight, into an odorous liquid which yields crystals on cooling. At temperatures higher than its point of fusion, it may be decomposed into benzoic acid and benzoate of ammonia, which may be distilled and condensed in red drops, associated with an oily product having an agreeable odour resembling that of the tonka bean. Towards the end of the distillation, cyanhydric acid comes over, leaving a porous residue of carbon. Hippuric acid requires 400 parts of cold water for its solution, but is very soluble in hot water, and still more so in alcohol. In ether it is but slightly soluble. Concentrated sulphuric acid dissolves hippuric acid without discoloration; but at a higher temperature the solution blackens, evolving sulphurous acid, and a sublimate of benzoic acid. By nitric acid it is transformed into benzoic acid. In chlorohydric acid it dissolves without alteration. Peroxide of manganese and sulphuric acid, aided by heat, convert it into carbonic acid, ammonia, and benzoic acid. Boiled in water with the puce oxide of lead, it is transformed into the amiduret of benzule, or benzamide and carbonic acid. Distilled with four times its weight of slaked lime, this acid is converted into ammonia and a volatile oil called benzole, with a greyish residuum.

5316. When the urine of the horse is left to itself for a long while, or exposed to a rapid evaporation, only benzoic acid is found therein. It is in combination with ammonia or soda that this acid exists in urine.

5317. *Of the Hippurates.*—The combinations of hippuric acid with the oxides of metals proper, excepting iron, being more soluble in water when boiling than when cold, may be obtained in crystals, from an aqueous solution made at the temperature of ebullition, and subsequently cooled. By reaction with the hydrates of potash or lime, the hypurates yield ammonia, and an oily liquid, probably benzole.

5318. *Of Formobenzulic Acid*,  $Bz H^6 2HO^3 + HO$ .—This acid consists of formic acid and the hydruret of benzule, being created during the reaction of chlorohydric acid with the distilled water of bitter almonds, comprising, of course, the hydruret and cyanhydric acid (3055). The cyanhydric acid is decomposed into ammonia and formic acid. With this acid, while nascent, the hydruret combines.

5319. Formobenzulic acid, thus obtained, is in the state of pulverulent white crystals, fusible into an oily liquid at the expense of the water of crystallization, and capable, when aided by heat, of decomposing the acetates, carbonates, and benzoates. Its aqueous solution, when submitted to chlorine, to nitric acid, or to peroxide of manganese with diluted sulphuric acid, is resolved into carbonic acid, and the hydruret which forms its characteristic ingredient. It has the same capacity of saturation as formic acid. Of course it is a monobasic acid.

## OF THE ACID OILS OF SPIREA ULMARIA AND GAULTHERIA.

**5320.** As the results obtained by Mr. Procter, Jr., respecting the analogy & identity of the oils of gaultheria and spirea ulmaria, must create a desire to be acquainted with both, I have abstracted, with some changes in the style, from Gregory's translation of Liebig, so much as relates to saliculous acid, and have subjoined some quotations from Procter's memoir. I have not thought it necessary to alter the names employed by Gregory. Yet salicyl might be considered as a compound halogen body, combining with hydrogen, like cyanogen in cyanhydric acid, in which case, consistently, its name would be salicohydric acid. Of course this acid, in combining with oxybases, would have to be considered as generating salicides of their radicals respectively. Were this mode of contemplating the subject admissible, the atom of hydrogen which forms the radical in salicohydric acid, must be supposed to be converted into water by uniting with an equivalent of oxygen from the oxybase of any radical with which it may combine. It must, however, be evident, that the adoption of these innovations in nomenclature would be attended by great practical inconvenience from the consequent multiplication of discordant names. And were it otherwise, I should not deem it judicious to make the suggested changes, because our knowledge of such compound radicals as salicyl, and of the state in which they exist in their alleged combinations, is altogether hypothetical and insusceptible of any conclusive proof. Salicylous acid may be viewed as a hydrated oxacid,  $C^{14}H^5O^3 + HO$  (3063, 5343).

*Of Salicylous or Saliculous Acid, also called the Hydruret of Salicyl, but more properly considered as Salicohydric Acid,  $C^{14}H^5O^4 + H$ .*

**5321.** This acid was first discovered by Pagenstecher in the volatile oil of spirea ulmaria; by Piria as a product of the decomposition of salicine, who ascertained its nature and composition.

**5322.** To obtain it, the oil of spirea is distilled with an aqueous solution of potash in excess as long as any oil distils. The residue, a solution of saliculate of potash, is supersaturated with dilute sulphuric acid, and again distilled, when saliculous acid comes over with the vapour of water. Or, according to Piria, a mixture of one part of salicine, one part bichromate of potash, two and a half of oil of vitriol, and twenty of water, is to be subjected to distillation. The salicine being dissolved in part of the water, and the acid diluted with the rest, the whole materials are mixed in a retort, when heat is excited with a gentle effervescence. When this ceases, the distillation should be commenced. Half a pound of salicine yields about two ounces of saliculous acid. In both processes the distilled liquid contains saliculous acid, which separates from the water. It is purified by washing with water and rectification with chloride of calcium.

**5323.** It is a colourless or pale yellow, oily, inflammable liquid; sp. gr. 1.1731, which boils at  $370^\circ$ , or, according to Piria, at  $380^\circ$ , and congeals at  $-4^\circ$ . It has a burning taste, and a pleasant aromatic odour; is somewhat soluble in water, and mixes, in all proportions, with alcohol and ether. Its solution first reddens, then bleaches litmus. It is decomposed by concentrated sulphuric acid. When placed in contact with chlorine or bromine, one eq. hydrogen is removed, which, with those elements severally, forms chlorohydric or bromohydric acids; and is replaced by one eq. chlorine or bromine, producing chlorosaliculic, or bromosaliculic acid. Saliculous acid, treated with an excess of hydrate of potash, evolves hydrogen

gas, while saliculinic acid is formed. Saliculous acid likewise disengages hydrogen by reaction with potassium, forming saliculite of potash.

5324. *Saliculous Acid with Bases*.—Saliculous acid combines with metallic oxides, its basic water being replaced by one eq. metallic oxide. The resulting fixed alkaline and ammoniacal saliculites are soluble, and capable of an alkaline reaction. The rest are insoluble. Most of them are yellow, and contain water of crystallization. A solution of the acid colours the salts of peroxide of iron of an evanescent purple colour. In acetate of copper it produces a green precipitate. Saliculous acid is separated from the saliculites by the stronger acids.

5325. *Saliculite of Ammonia*, or salicide of ammonium, a solid yellow mass, is prepared by adding concentrated liquid ammonia to saliculous acid. It is without taste, having a faint odour of roses; sparingly soluble without change of colour, in cold water and alcohol; more readily dissolved by hot alcohol. By the cooling of a saturated solution, transparent pale yellow needles are obtained. It is spontaneously decomposed if kept moist; becoming black, semi-fluid, and exhaling ammonia with a penetrating smell of roses. Dry saliculous acid readily absorbs dry ammonia; and the compound, according to Ettling, contains three atoms of the acid and two atoms of ammonia.

5326. *Saliculamide*.—If one measure of saliculous acid be dissolved in three of alcohol, and ammonia added by successive drops, the liquid concretes into a solid mass of fine yellow needles. With the aid of a moderate heat these crystals dissolve; and the solution, by repose, deposits golden yellow, brilliant, transparent prisms, which, when dry, are hard and unverifiable. Here three atoms of the acid (or one atom considered as a basic acid) are acted on by two of ammonia, six atoms of water being eliminated. The alcoholic liquid in which these crystals have been formed, no longer able, even at a boiling heat, to dissolve them. They now require a threefold quantity of alcohol. This would indicate, that at first salicide of ammonia is formed, which, by a longer contact with ammonia, and slow separation of the crystals, passes into saliculamide. This body is decomposed by a high temperature. Heated with acids and alkalis, it is dissolved into saliculous acid and ammonia. It is insoluble in water. Formula,  $C^{14} H^{18} O^8 N^2$ .

5327. *Saliculite of Potash; Neutral*.—This is best obtained by adding saliculous acid to a warm solution of potash in alcohol, and allowing the whole to cool, when the salt separates almost pure in the form of four-sided pearly tables, nearly colourless, very soluble in water, spontaneously decomposed by exposure to the air in a moist state. It contains water of crystallization, which is expelled by a heat of  $212^{\circ}$ . Formula,  $2(C^{14} H^3 O^8) + KO$ .

If the neutral salt be dissolved in hot alcohol, and saliculous acid added, acid salt is deposited, on cooling, in yellowish-white, long, fine, and brilliant needles. When dry it becomes yellow at a temperature of  $230^{\circ}$ . Water decomposes it into a neutral salt, and saliculous acid, which separates.

5328. *Saliculites of Soda, Lime, Baryta, and Magnesia*, may be formed directly. They have the properties of the potash salt. The soda salt contains two atoms of water of crystallization, removable by a heat of  $230^{\circ}$ . There is likewise an acid salt of soda in fine shining needles. Saliculite of copper is anhydrous and green. The salts of zinc and mercury are yellow and insoluble.

5329. *Basic Saliculite of Lead*.—Saliculous acid being dissolved in dilute alcohol, and acetate of lead added to the boiling solution, on cooling



is deposited, and may be separated by boiling alcohol from any acid. It is a lemon-yellow powder, which, when heated, froths up, in water and acid; insoluble in water. Its formula is  $C^{14} H^5 O^3 +$  If saliculous acid be added to diacetate of lead, a yellow powder of the same composition is precipitated.

*Saliculite of Silver.*—A solution of nitrate of silver causes, with saliculite of potash, a greenish-yellow precipitate, which, when heated, without disengagement of gas, the vessel being silvered by the metal.

*Melanic Acid*,  $C^{10} H^4 O^5$ .—Discovered by Piria. When saliculite is exposed to the air, it acquires a green colour, which, after a while, becomes black. When no further change is perceived, the salicid is completely converted into acetic acid and a black powder. The acid thus formed is in the exact proportion to combine with all the hydrogen contained in the original salt. The black powder possesses acid properties, and unites with bases; from which circumstance it has received

Three equivalents of oxygen and two of water unite with one atom of salicid, and convert its acid into one equivalent of acetic, and one equivalent of melanic acid.

*Saliculic Acid*,  $C^{14} H^5 O^5 + HO$ .—Discovered by Piria. This acid is generated by heating saliculous acid with caustic potash. The mixture at first assumes a brown colour, but the heat must be continued until it becomes white. At this time hydrogen is disengaged. The residue is to be dissolved in water and treated with a mineral acid, which separates the salicid. In order to obtain it pure it must be repeatedly crystallized. Salicid acid is likewise formed, when coumarin (stearopten of the Tonka bean) is treated with potash in a similar manner.

Saliculic acid sublimes without decomposition, and may be thus obtained in the form of long crystalline needles, very similar in their appearance to benzoic acid. It crystallizes from water in fine tufts. This acid dissolves with difficulty in cold water, but very easily both in hot water and in alcohol. Sulphuric acid decomposes it when they are heated.

The salts of this acid have been little examined. The saliculate of potash is insoluble in water.

*Chlorosaliculic Acid*, also called chloride of salicyl, chloride of

Dry chlorine gas is passed through anhydrous saliculous acid as salicid, and hydrochloric acid is disengaged. On cooling, the compound becomes solid and crystalline. It may be purified by crystallization from a solution in alcohol, which deposits it, on cooling, in the form of pale yellow, rhombic tables, of a pearly lustre, having a peculiar aromatic odour, and the capability of being sublimed without alteration. It is inflammable, burns with a green flame, is insoluble in water, but soluble in alcohol. It combines with alkalis, and may be separated from them by acids. An alcoholic solution gives with acetate of copper a yellow precipitate, and with acetate of lead a yellow precipitate. Persalts of iron are tinged by it of a dark blue. When heated with potassium, it is decomposed with heat and light. Ammoniacal gas converts it into chloroform.

This chloracid is distinguished from all analogous compounds of chlorine with compound radicals, by its power of combining with bases, and by the action of those bodies. It forms with metallic oxides pecu-

liar salts, in which one atom of chlorosaliculic acid is combined with one atom of metallic oxide, supposing the oxygen and chlorine to change places, so that they may be considered as compounds of saliculic acid with metallic chlorides,  $C^{12}H^5O^3 + MCl$ , like the compounds of the chlorochromic acid with alkalis or metallic chlorides. Formula of chlorosaliculic acid,  $H^5O^4Cl$ .

5338. *Chlorosaliculimide*.—Formed by the action of ammonia on the preceding compound. Dry ammonia is passed over chlorosaliculic acid in a proper apparatus as long as water is formed. The new substance remains behind in a state of purity. It forms a solid deep yellow mass, insoluble in cold water, decomposed by hot water, acids, and alkalis, with the evolution of ammonia and chlorosaliculic acid. Three atoms of chlorosaliculic acid with two of ammonia, produce six atoms of water and one atom of chlorosaliculimide,  $C^{12}H^{15}O^{12}Cl^3 + N^2H^6 = C^{12}H^{15}Cl^3N^2O^6 + 6H_2O$ .

5339. It hence appears to be saliculimide, in which three atoms of hydrogen are replaced by three atoms of chlorine.

5340. *Bromosaliculic Acid*.—This compound, in its preparation, properties, and action with ammonia, is completely analogous to the preceding.

5341. *Iodosaliculic Acid*.—Saliculous acid dissolves iodine in great quantity, without apparent decomposition. But iodosaliculic acid may be obtained by distilling iodide of potassium with chlorosaliculic acid. It sublimes in the form of a dark-brown fusible mass, analogous in its relation to the two preceding compounds.

5342. *Nitrosaliculic Acid*,  $C^{12}H^5N^4O^{12}$ .—Saliculous acid, washed with moderately strong nitric acid, is converted, with disengagement of nitrous acid, into a crystalline mass of nitrosaliculic acid, which is purified by washing with water, solution in alcohol, and crystallization. By spontaneous evaporation, the alcoholic solution yields small transparent prisms of a golden-yellow colour, sparingly soluble in water. The solution stains the skin and nails permanently yellow, precipitates the salts of lead yellow, and those of copper green. It is inodorous, but has an acrid taste, exciting cough. Heated with potassium, it is decomposed with explosive ignition. It combines with alkalis to form crystallizable compounds, which decompose when dried and heated. Ammonia colours the acid a deep blood-red. Chloride of iron is coloured cherry-red by it. These compounds demand a more accurate study.

5343. Fuming nitric acid acts violently on saliculous acid, producing a volatile yellow matter, and a fixed residue containing a crystallizable substance not yet examined.—*Gregory's Translation from Liebig.*

### *Of the Acids from the Oil of Gaultheria.\**

5344. From the observations and experiments of Mr. Procter, Jr., published in the American Journal of Phar-

\* "Oil of *Gaultheria Procumbens*.—This volatile oil is extensively used by the pharmacutists of this country to flavour syrups, etc. Most of the oil used in this city is obtained from distillers residing in New Jersey, in which State the plant yielding it grows in great abundance. As usually found in the shops, it has a more or less intense red colour; but when recently distilled it is colourless, or nearly so. Its density, as the result of several careful observations, is 1.173, and its boiling point  $412^\circ$ , Fahr.; the mercury remaining stationary at that point. Its taste is burning and aromatic; it is slightly soluble in water, to which it communicates its odour and taste; and it mixes with alcohol and ether in all proportions."—Procter, page 212.

lacy for October last (1842), it appears that there is a great resemblance between the habitudes of oil of gaultheria, and that from spiræa ulmaria, described above as saliculous acid. It appears either that salicyl exists in the oil of gaultheria, and is productive of compounds resembling those produced by like reactions with the oil of spiræa ulmaria; or that another compound radical exists in the oil of gaultheria, which has a close analogy in properties to salicyl.

5345. I will here quote the account given by Mr. Procter, Jr., in which the habitudes of the two oils in question are contrasted.

5346. Mr. Procter premises in the following words:—"For several years past it has been supposed\* that the volatile oil of the gaultheria procumbens, either from the analogy of their odour or specific gravity, possessed similar properties with the oil of spiræa ulmaria, without any steps having been taken to ascertain the correctness of the supposition. The observations which follow are intended to throw light on this subject. The chemical characteristics of oil of gaultheria have been found, in many instances, to accord with those described as peculiar to saliculous acid, yet several instances occur to the contrary.

5347. "They have the same density, and the aqueous solution of each colours the persalts of iron purple. The compounds which potassa, soda, and oxide of copper form with oil of gaultheria, are very like the salts of saliculous acid with those bases.

5348. "The action of an excess of caustic potassa with heat produces a crystalline body, identical in all its reactions with saliculous acid, as described by Piria.

5349. "The compound of oil of gaultheria and potassa, when exposed to be combined influence of moisture and the atmosphere, undergoes a decomposition similar to that of saliculite of potassa.

5350. "The reactions of chlorine and bromine with oil of gaultheria yield compounds similar to those with saliculous acid; and nitric acid also produces results of an analogous character.

5351. "On the contrary, the boiling point of oil of gaultheria is many degrees higher than that of saliculous acid. Ammonia forms a compound with it which differs from saliculite of ammonia in not being decomposed by acids with the separation of the oil, nor by potassa with the separation of ammonia. All endeavours to form the body called *saliculimide* by Liebig, with the process he gives, were ineffectual. The compounds of baryta and lead with oil of gaultheria are *white*, while the saliculites of those bases are *yellow*. But the most striking difference between these substances is, that when oil of gaultheria is boiled with solution of potassa, it is not recoverable by means of an acid, as saliculous acid is. Under these circumstances a crystalline substance is precipitated, which is the same acid that results from heating the oil with an excess of potassa."

\* Dr. Wood, U. S. Dispensatory.

5352. "Dropped into a concentrated solution of \_\_\_\_\_ or soda, the oil is instantly solidified, becomes white, and separates from the alkaline solution while heat is disengaged.

5353. "Oil of gaultheria decomposes the carbonates of potassa and soda gradually, without heat; but if gently warmed, the evolution of carbonic acid is evident.

5354. "Chlorine and bromine, when brought into contact with oil of gaultheria, combine with it; the mixture becomes very hot, and hydrochloric and hydrobromic acids are evolved. Iodine is dissolved by the oil, forming a deep red solution without combining with it, as heat dissipates the iodine without the production of any hydriodic acid.

5355. "Nitric acid of density 1.40, assisted by heat, converts oil of gaultheria into a crystalline substance having acid properties, whilst nitrous acid fumes are evolved. If fuming nitric acid be employed, the reaction is violent, without the assistance of heat, and a different product is obtained.

5356. "When oil of gaultheria is added to concentrated sulphuric acid, the latter becomes slightly coloured, and, if heated, the odour of the oil is destroyed.

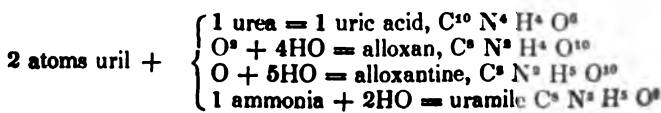
5357. "When oil of gaultheria is distilled with solution of potassa in excess, the distilled liquid has neither the odour nor taste of the oil, and consequently its constitution differs from that of the oil of *spiraea ulmaria*, which, under the same circumstances, yields a volatile oil distinct from salicylic acid, that acid remaining combined with the potassa."

5358. For further particulars respecting the results of Mr. Procter's meritorious investigation, I refer to his memoir. I hope that the brilliant success which has attended his efforts, may cause them to be emulated by many of his countrymen.

#### OF URIL, Or Cyanozalic Acid.

5359. The preceding appellations have been given to a hypothetical combination of carbon, nitrogen, and oxygen, of which the formula is  $C^8 N^3 O^4$ , and which may be considered either as a compound of carbonic acid and cyanogen, or as resulting from the substitution of cyanogen for one of the three atoms of oxygen in oxalic acid. Thus the formula of the latter being  $C^2 O^4$ , that of uril will be  $C^8 O^4 + Cy$ . It may be remembered that urea, a crystallizable matter of the urine, has been mentioned as being equivalent to cyanate of ammonia,  $C^2 NO + NH^4 O$ , or more properly a cyanate of the oxide of ammonium, this oxide comprising the elements of one atom of ammonia,  $NH^3$ , and one of water,  $HO$  (1307).

5360. This being premised, the following formulæ of the combinations of uril will, it is presumed, be understood.



*Of Uric Acid, and various Substances to which it gives rise.**Of Uric Acid, C<sup>10</sup> H<sup>4</sup> O<sup>6</sup> N<sup>4</sup>.*

5361. As the most frequent and abundant material in urinary calculi, uric acid, and the substances which contribute to its formation, or which may be derived from it, merit the most sedulous attention.

5362. This acid is an ingredient in the urine of men, and generally in that of carnivorous animals, forming, as already mentioned, calculi, depositions from urine, and gouty or arthritic concretions. In the state of urate of ammonia, it constitutes the greater proportion of the excrement of the boa constrictor and other serpents; also of birds, more especially those of the carnivorous species. I found it to abound in that of a young eagle. An accumulation of the excrement of certain aquatic birds, containing a large amount of this acid, on some islands near the coast of Peru and Chili, under the name of guano, is much used as manure.

5363. I infer that the best process for obtaining uric acid is as follows:—Boil the substance from which it is to be extracted in a dilute solution of caustic potash. On allowing the decoction to cool, urate of potash, which is almost insoluble in cold water, precipitates, leaving some impurities in solution. After being well washed with water, the urate thus separated is redissolved in a boiling solution of potash, next filtered, while hot, and afterwards added to an excess of chlorohydric acid maintained in a state of ebullition. The uric acid which precipitates, is to be rendered pure and white by repeated aqueous ablution.

5364. Liebig recommends, that in extracting uric acid from excrement, a solution of borax be employed, as it does not take up so large a portion of the impurities as caustic potash.

5365. Uric acid crystallizes in thin spangles, with a dazzling white satin lustre. It is insipid and inodorous. At a boiling heat the crystals sustain no loss of water. It is heavier than water, almost insoluble in that liquid when cold, and but little soluble in it when hot. The solution feebly reddens litmus.

5366. When to a well refrigerated aqueous solution of

borate of soda, holding uric acid dissolved, chlorohydric acid is added, the uric acid precipitates in a hydrated state, forming a transparent jelly, which, by a feeble heat, is converted into a crystalline powder, consisting of anhydrous uric acid.

5367. This acid is soluble in concentrated sulphuric acid, but separates on dilution with water. It is more soluble in concentrated chlorohydric acid than in pure water.

5368. Subjected to dry distillation, it yields the same products as urea, that is to say, cyanic acid, cyamelide, cyanhydric acid, a little carbonate of ammonia, and a brown and carbonaceous residue very rich in nitrogen. During this decomposition, the hydrated cyanic acid and ammonia unite in the neck of the retort, forming urea.

5369. In dilute nitric acid, uric acid dissolves, with lively effervescence, from the escape of equal volumes of carbonic acid and nitrogen. The resulting solution contains alloxan, alloxatin, urea, parabanic acid, and ammonia.

5370. By the addition of an excess of ammonia, the concentrated liquid becomes purple red, from the generation of murexide. This effect is one of the means of recognising the acid.

5371. Fused with hydrate of potash, uric acid produces, with the alkali or its metal, a carbonate, a cyanate, and a cyanide.

5372. Subjected to boiling water with the bioxide of lead, it is resolved into allantoin, oxalic acid, and urea. Heated to  $320^{\circ}$ , with a little water in a tube hermetically sealed, this acid is dissolved, without the evolution of gas, forming a yellow transparent liquid, which, on lowering the temperature, assumes a gelatinous appearance.

5373. Uric acid is peculiar in combining with metallic oxides, without abandoning water. The urates of the alkalis and alkaline earths are little soluble in cold water, but very soluble in this liquid when boiling, the solubility being augmented by an excess of alkali. The urates formed with other metallic oxides and with ammonia, are white and insoluble. All the urates are easily decomposable by acids, even by the acetic acid. When first liberated, uric acid assumes the form of a jelly, which is soon changed into fine brilliant spangles.

**5374.** *Allantoin* is a substance arising from the urine of a fetus in the uterus of a cow, and may be obtained from the waters of the allantoin of this animal, by evaporation and crystallization. It may be more easily procured by the following means:—To uric acid, diffused through twenty parts of boiling water, freshly prepared, bioxide of lead is to be added as long as the colour is affected. The boiling liquor is to be filtered, and evaporated until crystallization commences. It is then allowed to cool in a quiescent state. By this procedure the allantoin separates in crystals, an oxalate of the protoxide of lead being simultaneously produced.

**5375.** In order to understand this process, the composition of the materials and products should be remembered. They are as follows:—Uric acid,  $C^{10} H^4 N^4 O^6$ ; bioxide of lead, one atom of protoxide, one of oxygen; urea,  $C^2 N^2 H^4 O^2$ ; allantoin,  $C^4 N^4 H^5 O^5$ ; oxalic acid,  $C^2 O^4$ .

**5376.** Hence, assuming that five atoms of water are taken up, and one atom of oxygen for each of the four atoms of bioxide of lead, the materials are:—

Two atoms of uric acid, - - -	$C^{20} H^8 N^8 O^{12}$
Five water, - - - - -	$H^5 O^5$
Four oxygen, - - - - -	$O^4$
	<hr/>
	$C^{20} H^{13} N^8 O^{21}$
	<hr/>
The products are two urea, - - -	$C^4 H^8 N^4 O^4$
Four oxalic acid in the oxalate, - -	$C^8 O^{12}$
One allantoin, - - - - -	$C^4 H^5 N^4 O^5$
	<hr/>
	$C^{20} H^{13} N^8 O^{21}$
	<hr/>

The protoxide of lead being in both of the aggregates, does not affect the result by being omitted from both.

**5377.** It is from the results of this reaction between uric acid and bioxide of lead, that Liebig has inferred the existence of uril as above mentioned (5319).

**5378.** *Alloxan*, or erythric acid, is one of the products which have resulted from the decomposition of uric acid. To prepare alloxan, one part of uric acid is to be added to four of nitric acid, of a density between 1.41 and 1.5. As the reaction causes much heat and effervescence, the uric acid should be added in successive small portions. Little white granular brilliant crystals are gradually formed, until the whole becomes one aggregate of them, which, after being allowed to drain in a glass funnel, must be dried on porous brick, or porcelain earth. By re-solution and re-crystallization, the crystals of alloxan, thus formed, will be rendered quite pure.

**5379.** Alloxan crystallizes in octahedra, with rhomboidal bases, colourless, transparent, very brilliant, and often of an inch in diameter. They are efflorescent, losing 25 per cent. of water. By a gentle heat, alloxan, thus crystallized, is rendered anhydrous. It may be obtained in anhydrous crystals, in the form of oblique rhomboidal prisms, which resemble rhomboidal octahedra with truncated summits, from an aqueous solution of alloxane saturated while hot. It is very soluble in water, has a nauseous smell, and a salt and feebly astringent taste. It reddens vegetable colours, and tinges the skin purple. By reaction with alkalis, it is decomposed into alloxanic acid. Boiled with an alkali, it is transformed into urea and mes-

oxalic acid. It is transformed into allo: chloride of tin, or metallic zinc, and chloronyric acid. An excess of ammonia transforms it into mycomelic acid. Nitric acid converts it into parabanic acid; sulphuric or chlorohydric acid into alloxantin; sulphurous acid and ammonia into thionurate of ammonia; alloxantin and ammonia into murexide. Subjected, simultaneously, to an alkali and a salt of protoxide of iron, it produces an indigo-blue liquid. With metallic oxides it cannot combine without decomposition.

5380.\* *Alloxanic acid* (supposed anhydrous),  $C^8 N^2 HO^4$ ; is produced by the metamorphosis of alloxan by caustic alkalis. The anhydrous acid contains the elements of half an atom of alloxan, minus one atom of water.

5381. *Mesoxalic acid* (hydrated),  $C^8 O^8 H + 4HO$ ; or rather  $C^8 O^8 + 2HO$ , is one of the products of a solution of alloxanate of baryta or strontian, saturated at a boiling heat. Also, when a solution of alloxan is poured, drop by drop, into a boiling solution of acetate of lead, a very heavy granular mesoxalate of lead precipitates, while nothing remains in the acid liquor besides the excess of acetate of lead and pure urea. Both this and the preceding acid may be separated and crystallized. They are powerful acids.

5382. *Mycomelinic acid*,  $C^{12} N^2 H^{10} O^{10}$ , is formed on adding an excess of ammonia to a solution of alloxan, and raising the mixture to the boiling point. It is almost insoluble in cold water, and is thrown down as a yellow gelatinous precipitate, which becomes a yellow porous powder on drying.

5383. *Parabanic acid*,  $C^8 N^2 O^4 + 2HO$ , is one of the products of the decomposition of uric acid or alloxan by nitric acid, discovered by Liebig and Wöhler. It is prepared by dissolving one part either of uric acid or alloxan in eight parts of nitric acid of ordinary strength, evaporating the liquor to a syrup, and allowing it to crystallize.

5384. It has a very sour taste, resembling that of oxalic acid, and forms thin transparent six-sided prismatic crystals. It is very soluble in water and does not effloresce; it is in some degree volatile.

5385. *Oxaluric acid*,  $C^8 N^2 H^5 O^7 + HO$ , is formed on adding ammonia to a boiling solution of parabanic acid, or on supersaturating with ammonia a solution, recently prepared, of uric acid in nitric acid, which yields, by evaporation, crystals of oxalurate of ammonia. The acid, when separated, is a light brilliant white crystalline powder; its taste is very sour, and reddens litmus. Its aqueous solution is decomposed completely by ebullition, and resolved into oxalic acid and oxalate of urea. It is formed by the combination of the elements of parabanic acid with two atoms of water. The crystallized acid contains the elements of two atoms of oxalic acid as of one atom of urea, and may be considered as uric acid in which the  $HO$  is replaced by oxalic acid.

5386. *Thionuric acid*,  $C^8 N^2 H^5 O^6 (S^2 O^6) + HO$ , is a bibasic acid produced by the simultaneous action of sulphurous acid and ammonia upon alloxan. Liberated from thionurate of lead by sulphuretted hydrogen, crystallizes in very thin needles, is persistent in air, very soluble in water and has an acid taste. It contains the elements of one atom of alloxan, a

\* Finding Graham's Elements to contain an abridgment of the account given by Liebig, of the compounds, or products, of uric acid, I have made a free use of it, with such changes in the language as to make it my own, where it was not such as should have used. In some cases I have made a similar use of Kane's Elements and of Gregory's Translations from Liebig, especially in the account of salicylic acid and its compounds.



monia, and two atoms of sulphurous acid. On heating thionuric acids of oxygen of the alloxan reunite with two atoms of sulphur to form sulphuric acid, while the elements of urile, ammonia, combine and give rise to uramile.

*Uramile*,  $C^8 N^3 H^5 O^6$ , is prepared by adding hydrochloric acid to a boiling solution of thionurate of ammonia, till it is strongly acid; the heat is continued till the liquid begins to become turbid; it is then cooled for crystallization. Uramile crystallizes in thin and presents itself in the form of a brilliant white powder composed of thin silky needles. It is sparingly soluble in hot water, insoluble in cold water, dissolves in ammonia and caustic alkalis, is precipitated, without alteration, by acids. Either diluted acids of potash, boiled upon uramile, convert it into uramile acid, ammonia. The ammoniacal solution of uramile becomes purplish, and deposits crystalline needles of a green colour and metallic lustre on contact with oxide of mercury or oxide of silver, it is decomposed by boiling, into murexide, and at the same time reduces the oxides to their metallic state.

*Uramile acid*,  $C^{16} N^5 H^{10} O^{15}$ , is prepared by dissolving thionuric acid in cold water, adding to the saturated solution a small quantity of sulphuric acid, and evaporating by a water-bath. After a time, uramile is deposited in transparent four-sided prisms of a vitreous lustrous appearance. It is soluble in six or eight parts of cold water, and in two parts of boiling water, forming a feebly acid solution. For the preparation of uramile acid, two atoms of uramile unite with the elements of one atom of water, yielding up, at the same time, the elements of one atom of ammonia.

*Alloxantin*.—Formula,  $C^8 N^3 H^5 O^{10}$ . Alloxantin was first observed by Prout among the products of the decomposition of uric acid, and more lately produced and studied by MM. Liebig and Wöhler, to whom several processes are given for its preparation. 1. *From uric acid*.—One part of uric acid is boiled with thirty-two parts of water, and a little sulphuric acid added, by small portions at a time, till the uric acid is dissolved, and the liquor evaporated to two-thirds. In the course of the evaporation, or sometimes a few hours, the alloxantin is deposited in crystals, which are purified by new crystallizations. 2. *From alloxan*.—It is obtained in large quantity by conveying a stream of sulphuretted hydrogen gas through a solution of alloxan. Sulphur is first deposited, and then the whole mass of crystals of alloxantin, which are separated from the solution in boiling water. The alloxantin crystallizes by evaporation of purity. 3. On exposing a solution of alloxan to the action of an voltaic battery, oxygen is evolved at the anode, and alloxantin is deposited at the cathode in crystalline crusts.

Alloxantin crystallizes in oblique prisms of four sides, which are slightly yellow, hard, and easily reduced to powder; they bear being impregnated with ammonia, and acquire a green metallic lustre; they are not altered at  $212^\circ$ , but at  $302^\circ$  ( $150^\circ$  centig.) lose three atoms of water; are sparingly soluble in cold water, more soluble in boiling water, reddens litmus. Alloxantin heated in chlorine-water, or in nitric acid, is changed into alloxan. With salts of silver it produces a black precipitate of metallic silver. It is decomposed by alkalis; and produces, in its solution, a violet precipitate, which is made to disappear by heat, and finally disappears. By the action of boiling sul-

phuric acid, two atoms of alloxan are converted, t concurrent with the decomposition of two atoms of water, into one atom of alloxantin, three atoms of oxalic acid, two atoms of ammonia, and two atoms of carbonic acid.

5391. The circumstances of the formation of alloxantin are thus explained by M. Liebig. By the action of nitric acid, the uril of the uric acid combines with one atom of oxygen, and with the elements of five atoms of water, giving rise to one atom of alloxantin, and to quadroxide of nitrogen,  $\text{NO}^4$ , which, in contact with water, is converted into nitrous and nitric acids; the nitrous acid is decomposed, and half of the urea set at liberty; while the other half of the urea forms, with nitric acid, nitrate of urea. In the process with sulphuretted hydrogen, one atom of oxygen of the alloxan combines with hydrogen from the sulphuretted hydrogen to form water, which remains in the constitution of the alloxantin; the sulphur set free is deposited.

5392. *Products of the decomposition of Alloxantin.*—When a stream of sulphuretted hydrogen is carried into a boiling solution of alloxantin, more sulphur is deposited, and on saturating the solution with ammonia, a salt crystallizes in thin colourless needles, of which the formula is  $\text{C}^8 \text{N}^8 \text{H}^7 \text{O}^8$ , which is considered a compound of a new acid, *dialuric acid*, with ammonia. This acid is resolved into new products when liberated by another acid; one of these produced by exposure to air, and evaporation of the solution of the ammoniacal salt in dilute sulphuric or hydrochloric acid, is *dimorphous alloxantin*, a body having the same composition as alloxantin with a different form. On mingling boiling solutions of sal ammoniac and alloxantin, the mixture becomes suddenly of a purple-red colour, then gradually loses its colour, becoming turbid, and deposits colourless brilliant plates of uramile, which become rose-red on drying. The liquid contains after its decomposition, alloxan and free hydrochloric acid. When a solution of alloxantin is heated with caustic ammonia, uramile and mycomelinate of ammonia are first formed, but are decomposed into other products by the prolonged action of ammonia and air. A recent solution of alloxantin in ammonia gradually absorbs oxygen from the air, and deposits crystals of oxalurate of ammonia.

#### Murexide.

5393. Formula,  $\text{C}^{12} \text{N}^5 \text{H}^6 \text{O}^8$  (Liebig and Wöhler). This beautiful product of the decomposition of uric acid was first described by Dr. Prost, under the name of purpurate of ammonia. Murexide may be formed by evaporating a solution of uric acid in dilute nitric acid, until it acquires a flesh-red colour, and treating it, when cooled to  $160^\circ$ , with a dilute solution of ammonia, till the presence of free ammonia is perceptible; the liquid is then diluted with half its volume of water, and allowed to cool. It may also be formed by the contact of ammonia with various other products of the reaction of nitric acid with uric acid, with ammonia, with or without the presence of atmospheric air.

5394. The following method, proposed by Liebig and slightly modified by Gregory, appears to be the easiest and most certain, and also most productive:—Seven grains of hydrated alloxan, and four grains of alloxantin, are dissolved by boiling in 240 grains of water, and the boiling solution added to 80 grains, by measure, of a cold and strong solution of carbonate of ammonia. This mixture has precisely the proper temperature, and deposits very fine crystals of murexide. The experiment is not so successful

on a large scale; probably because the liquid, by remaining longer warm, undergoes a partial change. It is best to try first a saturated solution of carbonate of ammonia in cold water. If it do not yield good crystals, add little water, and repeat the experiment till a solution of the carbonate is obtained, which gives a good result. The difficulty is owing to the spontaneous formation of different carbonates by the action of water on the carbonate of the shops; but when a proper solution is obtained, the experiment never fails.

**5395.** Murexide crystallizes in short four-sided prisms, of which two faces, like the upper wings of cantharides, reflect a green metallic lustre. The crystals are garnet-red by transmitted light. Their powder is reddish-brown, and acquires a green lustre under the burnisher. Murexide is but slightly soluble in cold water, but colours it of a magnificent purple; it dissolves, however, readily in water at  $158^{\circ}$ , and crystallizes again as the solution cools. It is insoluble in alcohol, ether, or in water saturated with carbonate of ammonia. But this substance cannot be purified or obtained in crystals of large size by crystallizing it from boiling water; for on boiling murexide in a small quantity of water for the time necessary to dissolve the whole, the crystals become colourless, and, upon cooling, a yellow gelatinous matter precipitates. Hence, probably, the slight uncertainty which attends even the best process for the preparation of this substance. Murexide dissolves in a solution of potash, producing a superb indigo-blue colour, which disappears with the application of heat, ammonia being disengaged. All the inorganic acids decompose murexide, precipitating from its solution murexan in small brilliant plates. Sulphuretted hydrogen decomposes it immediately into alloxantin, dialuric acid and murexan, while sulphur is set free.

**5396.** *Murexan*,  $C^6 N^2 H^4 O^5$ , was named purpuric acid by Prout. It is formed on dissolving murexide with heat in caustic potash, heating till the blue colour disappears, and then adding an excess of dilute sulphuric acid. It crystallizes in colourless plates which have a silky lustre, and are very brilliant; is insoluble in water and dilute acids; it dissolves in ammonia and other alkalis, in the cold, without neutralizing them. The properties of murexan closely resemble those of uramile. Like uramile, murexan, when oiled with water, red oxide of mercury, and a little ammonia, yields murexide. The composition of murexan and uramile, also, not differing much. In 100 parts, Dr. Gregory admits it to be possible that these two substances may be essentially the same.

**5397.** As the habitudes of uric acid, and of the substances from which it may be generated, or to which it may give rise, must be an object of interest to the surgeon and physician, I have deemed it proper to make a curious abstract respecting it from Graham. I do not, however, as respects other bodies, deem it expedient to go farther into these boundless regions of chemistry. The multiplication of compounds, rendered distinguishable in their properties by shifting the associations of ponderable, with imponderable matter, seems to be as unlimited as the images which may be produced in the kaleidoscope, by varying the relative positions of the coloured beads: and as, in a majority of instances, the compounds created by the changes alluded to, have either the electro-positive, or electro-negative character, which distinguishes acids and bases from other bodies; so it must happen that there will be a prodigious and increasing number of substances stumped with the attributes of acidity or basidity. Even adepts in the science will

find it impossible to retain any available knowledge of the details respecting such compounds, and of course, however important it may be to register all that is known of them in systematic works, in a text book it can answer no good purpose to dwell on that which could not be remembered even if it were once well learned.

5398. I propose, however, in an appendix, to give some alphabetical tables, in which the information, with which it were inexpedient to clog the body of this work, may be found.

*On the Influence of Benzoic Acid in lessening the Generation of Uric Acid in Human Urine.*

5399. Allusion has been made to the discovery, by Mr. Alexander Ure, that benzoic acid, taken into the human stomach, is converted into hippuric acid, causing a diminution of the uric acid generated in the urine. The observations and inferences of Ure have been confirmed by those of Bouchardat, who alleges, that in the case of a patient in the hospital of Hotel Dieu, at Paris, labouring under acute rheumatism, and whose urine was depositing an abundance of uric acid, the spontaneous deposition of the acid ceased after the due administration of benzoic acid: also, it is alleged by Mr. Garrod, that having repeatedly performed Ure's experiment, by swallowing from a scruple to half a drachm of benzoic acid at a time, he had always been enabled to obtain from his urine, passed three or four hours subsequently, on the addition of hydrochloric acid, from fifteen to twenty-nine grains of hippuric acid.\*

5400. There is, however, the opposite testimony of a commission of the French Academy of Sciences, drawn up by Gay Lussac and Pelouze, that they could not find any verification of the results of Mr. Ure. Agreeably to the knowledge which I have obtained respecting the manner in which such commissions are managed by some of the most distinguished of the academicians, I attach very little importance to their negative testimony. With excellent intentions, they are too much occupied, too much distracted, to do their duty well in such cases.

5401. I have not met with any statement tending to explain in what manner the elements of benzoic and uric acid can give rise to hippuric acid.

\* Bell's Pharmaceutical Journal, London, page 50. No. 12. June, 1842.

## OF ORGANIC ALKALIES OR BASES,

*called Vegetable Alkalies, Vegeto-Alkalies, or Alkaloids.*

2. The discovery of the substances which bear the mentioned names, is of the highest importance to medicine. It has enabled the physician to avail himself of five principles of some of the most powerful remedies with a certainty which was before unattainable. The patient, in lieu of being nauseated and even injured by medicines of which the greater part, perhaps the whole, may be hurtful, if not injurious, has to swallow nothing which is either inefficient or inefficacious, when judiciously prescribed.

3. The organic alkalies are entitled to rank as bases, from the definition of acidity, deduced from the practice of chemists, and given in this work (note 631), that what saturates a well defined acid must be deemed a base.

4. The compounds formed with acids by the alkaline bases under consideration, resemble those formed with metallic oxybases; their acids and ingredients being no less susceptible of precipitation by the appropriate tests. Thus sulphates are liable to be deprived of their acids by the action of baryta, their chlorides by solutions of silver or mercury. There is in this respect a striking difference between the properties of these organic alkaline bases and those which are formed of oxidized compound radicals, like the oxides of ethyl, formyl, and methyl, which cannot be transferred from one acid to another, unless in a nascent state, or under peculiar circumstances. Even when isolated, the last mentioned refuse to unite with hydrated acids, which is far from being the case with the alkaline bases in question. Generally, the latter differ very much from the former, in being much more soluble in alcohol than the former. In consequence of this last mentioned trait their reaction with vegetable colours is very feeble, being displayed more in their power of restoring such colours, than in directly producing the changes which result from the action of the inorganic alkaline bases.

5. The following table of the organic alkalies indicates their sources and composition:—

NAMES.	SOURCES.	COMPOSITION.*
Morphia† or morphine, .	Opium, .	$C^{34}H^{18}O^6N$
Paramorphia or paramorphine, .	Do. .	$C^{34}H^{12}O^6N$
Pseudomorphia or pseudomorphine, .	Do. .	$C^{27}H^{12}O^{14}N$
Codeia or codeine, .	Do. .	$C^{31}H^{20}O^2N$
Narcotina or narcotine, .	Do. .	$C^{40}H^{30}O^{19}N$
Narceia or narceine, .	Do. .	$C^{32}H^{24}O^{16}N$
Cinchonia or cinchonine, .	Peruvian bark, .	$C^{20}H^{19}ON$
Quinia or quinine, .	Do. .	$C^{20}H^{19}O^3N$
Aricina or aricine, .	Bark of an unknown tree, .	$C^{20}H^{12}O^3N$
Strychnia or strychnine, .	St. Ignatius's bean, nux vomica, &c. .	$C^{30}H^{16}O^3N$
Brucia or brucine, .	False Angustura bark, .	$C^{32}H^{18}O^6N$
Delphia or delphine, .	Stavesacre, .	$C^{27}H^{19}O^3N$
Veratria or veratrine, .	White hellebore and meadow saffron, .	$C^{34}H^{22}O^6N$
Sabadilla or sabadilline, .	Cevadilla, .	$C^{30}H^{12}O^5N$
Emetia or emetine, .	Ipecacuanha, .	$C^{37}H^{27}O^{10}N$
Solanina or solanine, .	Bittersweet and black nightshade, .	$C^{34}H^{62}O^{23}N$
Atropia or atropine, .	Belladonna, .	$C^{26}H^{25}O^{12}N$
Menispermia or menispermine, .	Cocculus Indicus, .	$C^9H^6N^6$
Melamia or melamine, .	Artificial, .	$C^3H^3O^3N^3$

RESIDUES OF JOSEPHUS	Formulae
Conina or conine, or conicine,	$C^7H^{11}NO$
Caffeina, caffeine, theine, or guaranine,	$C^8H^7N^3O^2$
Chelerythrina or chelerythrine,	
Colchicina or colchicine,	
Coradalina or coradaline,	
Curarina or curarine,	
Daturina or daturine,	
Cissampolina or cissampoline, or pelosine,	
Solanina or solanine,	
Hemlock or conien maculatum,	
Gurana, a paste made of the grain of paullinia sorbilis, or from coffee, or tea,†	
Colchicum autumnale,	
Root of corydalis bulbosa and fabacca,	
Curara poison,	
Datura stramonium,	
Root of cissampelos pariera,	
Several species of solanum; first shoots of potato,	
	Formulae not given.

\* The several formulæ indicate the quantity of each alkali in the anhydrous state, adequate to saturate one equivalent of an acid.

† There is some difficulty in adopting any satisfactory course respecting the terminating monosyllable in the names of the organic alkalies. By some British and American chemists, it has been considered important to have the alkaline character signalized by the termination in *e*, while the termination in *in* or *ine* should be retained in neutral or indifferent principles. But this plan has not been adopted by the French and other continental chemists, to whom we were first indebted for the discovery of the alkalies in question, and from whom, commercially, we have been in the habit of receiving supplies of them for the purposes of the arts. Moreover it has not been pursued in some of the recent British compilations of the highest rank. Hence, although in the United States Dispensatory, and Pharmacopœia, the termination in *e* has been adopted, quinine and narcotine are used much more, in common parlance, than quinia or narcotina. In fact, the claim of this last mentioned principle to be considered as an alkali, as well as those of several other principles, have been variously estimated at different times; and it constantly happens that a principle previously considered as neutral, is afterwards taken into the class of alkalies. Thus, for instance, caffeine, or theine, is to be treated as a base, agreeably to Berzelius' Report for 1841. Under these circumstances, I have concluded to mention both names, but employ that by which the principle in question is usually known.

‡ Berzelius' Report, 1841, 143.

5406. The salts, formed by the organic alkalis with oxacids, always contain the elements of an atom of water essential to their existence. In this respect they agree in their habitudes with the analogous ammoniacal compounds formed with the same acids. But in uniting with chlorohydric acid, or other halohydric acids,\* no water is requisite. In this respect also, there is an agreement between their habitudes and those of ammonia. Hence it might be reasonably inferred that in the one case the halogen body unites with a hydruret of the organic alkali, while in the other, the oxacid unites with an oxide of such a hydruret. This theory has made no change in the names of ammoniacal oxyacids; but as respects haloid compounds it has changed muriate of ammonia into chloride of ammonium, and induced an analogous result in the case of the ammoniacal compounds of each halogen body. Consistency then would seem to require that a like change should be made in the nomenclature of the compounds of the halohydric acids with the organic alkalis; but we have had no proof that any of these alkalis are metallized, and of course could not call muriate of morphia chloride of morphia. Under these circumstances, *chlorohydruret* is the name to which I would resort for any compound of chlorohydric acid with an organic base. In practice, however, until the relation between ammonia and these alkalis is better understood, it will be as well to employ the official appellation (*muriate*) above mentioned; keeping the other in view in order to prevent a theoretic misconception, that any combination can be formed with an organic base which merits to be designated as a muriate.

5407. The organic alkalis are, for the most part, products of vegetation; yet the following substances, not derived from vegetables, are alleged to be allied to the class of vegetable bases, *ammeline*, *melamine*, *aniline*, *urea*; also some substances obtained from the animal oil of Dippel, called severally *odorine*, *ammoline*, and *animine*.

#### *Organic Alkalies of doubtful Existence.*

5408. "The following bases are still problematical: *apirine*, *azaridine*, *blanchinine*, *buxine*, *carapine*, *castine*, *choccine*, *crotonine*, *cynapine*, *daphnine*, *digitaline*, *esenbeckine*, *eupatorine*, *euphorbine*, *fumarine*, *glancine*, *glaucopticine*, *jamaicine*, *menispermene*, *paramenispermene*, *pitayine*, *sanguinarine*, *staphisaine*, *surinamine*, *violine*. Besides two bases in Carthagena quinquina bark and in chinova bark." Graham's Translation from Liebig, 983.

*Of the State in which the Organic Alkalies exist in the Products of Vegetation, and the Means of extricating them, generally described.*

5409. The organic alkalis appear in almost every instance to exist in the vegetables to which they belong, in

\* Halohydric is the generic name which I apply to acids formed of a halogen body and hydrogen.



union with an acid. Thus, morphia is united with sulphuric and meconic acid, cinchonia and quinia with kinic acid, delphia with malic acid, and veratria with gallic acid. In some instances, the acids have not been specified; but the method requisite for the analysis, shows that they are present. The salt thus formed is entangled sometimes with resinous matter, sometimes with colouring matter, at others with fatty matter, and in a few instances with caoutchouc. In some cases several, in others all of these impurities may be present.

5410. In the extrication of the organic alkalies characterized, and situated as has been stated, the first object of the chemist will be to employ some solvent which will take up the native salt in which it exists. This may in many cases be effected by water alone; but an aqueous solution of some powerful acid, usually sulphuric or chlorohydric acid, appears to have been found preferable. The next step is decomposition of the salt formed with the organic base. This may, of course, be effected by any stronger base, and accordingly, potash, soda, ammonia, lime, and magnesia, have all been more or less employed. The alkali when insoluble in water, as happens in a great majority of cases, precipitates with or without the precipitant, accordingly as the compound which this forms with the acid is or is not soluble. In either case, the next object to be attained is to extricate the organic alkali from the impurities which may have been precipitated with it. These may consist of resinous matter, fatty matter, colouring matter, caoutchouc, &c. To remove these, washing with weak alcohol, ether and water, has been employed, or re-solution in an acid, and subjection to the depurating and decolorizing efficacy of animal charcoal. Repeated solution and recrystallization by means of alcohol, or acids, are also used to effect a final depuration. When the alkali to be extricated is soluble in water, and volatile as in the instance of conicine, the leaves, flowers, roots or seed, are subjected, with a weak, aqueous, alkaline solution, to the distillatory process. The water which distils in consequence, contains more or less of the organic alkali, as well as some ammonia resulting from its decomposition. Being first neutralized by diluted sulphuric acid, then concentrated by evaporation, and afterwards digested in a close vessel with ether, this liquid dissolves the organic alkali,

which may of course be easily isolated by subsequent exposure to a water bath sufficiently heated to expel the ether and ammonia.

5411. In some instances the decomposition of the native salts in which the organic alkalies are constituents, may be effected by acetate of lead. As this metal generally forms insoluble compounds with vegetable acids, by complex affinity the acid goes to the oxide of that metal, while the alkali combines with acetic acid. From the solution of the acetate thus formed, the lead of any excess of the acetate of lead may be precipitated by sulphydric acid.\*

### *Of Morphia or Morphine.*

5412. Morphia, the most important among the active principles of opium, was discovered by Serturner, of Eimbeck, in Hanover, and recognised by him as an organic alkali. This formed the first step in a new career in chemical discovery, having induced those subsequent researches by other chemists, to which we are indebted for our knowledge of the series of analogous principles mentioned in the preceding table.

5413. Morphia exists in opium in chemical union with meconic acid only, but is mechanically associated with various substances, of which an account has been given. (5172.)

5414. It is remarkable, that since we have learned the existence of morphia, it has become evident that the means of detecting its presence in laudanum, almost extemporaneously, had long been at hand in the shop of every druggist. Dr. Staples, a graduate of our school, demonstrated, about twenty years ago, that to cause a precipitation of crystals of morphia, it were only requisite to add to that tincture equal parts of liquid ammonia and alcohol. The crystals thus obtained, being redissolved by acetic acid,

\* The following process for elaborating the organic alkalies, suggested by M. O. Henry, is founded on the property of tannic acid to precipitate the organic alkalies in general.

Neutralize by potassa a clear infusion obtained by digesting the vegetable matter containing the alkali, or an extract procured from it, in tepid water, acidulated by sulphuric acid: add an infusion of galls so long as any precipitate ensues. The precipitate, after being washed with cold water, is to be thoroughly mingled with hydrate of lime, somewhat in excess, and being dried by the heat of boiling water, must be digested in alcohol or ether. The resulting solution, after filtration, is to be subjected to a heat sufficient to drive off the alcohol. The residual liquid, consisting of water which had been in combination with the alcohol, holds the alkali in solution, and after a few days repose deposits it in crystals.

and again precipitated by ammonia, may be purified of the matter by which they are, in the first instance, discoloured. A particular account of an improved process, devised by Dr. Staples, may be found in the United States Dispensatory, by the editors of which it is highly recommended.

5415. The following process, suggested by Wittstoch, is recommended as probably the best, by Kane.

5416. One part of opium, from eight to ten of water, with two of chlorohydric acid, are to be digested together for six hours. The solution being then decanted, the residue is to be subjected twice successively to the same ordeal. The resulting solutions being united, the whole is to be saturated with chloride of sodium. The matter which consequently subsides, is to be separated by filtration, and ammonia being added, in slight excess, to the filtered liquid, it must be allowed to rest undisturbed for twenty-four hours. The resulting precipitate is to be collected upon a filter, washed with a little water, dried, and digested in alcohol, of 0.820, which takes up the morphia. The greater part of the spirit being removed by distillation, morphia crystallizes on cooling in a state sufficiently pure.

5417. The effect of the chloride of sodium is to precipitate narcotina, and some other impurities. The meconin, codeia, thebaine, and some other principles, are retained in solution by the alcoholic mother liquor.

5418. Morphia crystallizes in rhombic prisms, containing for each atom, two of water, which are liable to be lost by efflorescence. It has an enduring bitter taste, and is almost insoluble in water, as it requires for solution 400 parts, even at the temperature of ebullition, and precipitates, almost entirely, as the liquid cools. It has an alkaline reaction, readily dissolves in alcohol, but sparingly in ether. It is also soluble in aqueous solutions of the alkalies and earths.

5419. As usually procured, this alkali, or any of its combinations, is reddened when brought into contact with nitric acid. The phenomenon is produced by the same acid on contact with other vegeto-alkalies, and, according to Kane, is not produced with morphia when absolutely pure. Subjected to chlorine in water, morphia is first made orange red, and then dissolved. On contact with morphia, the iodine of iodic acid is liberated. A solution

of sesquichloride of iron assumes a rich blue colour on the addition of morphia, or any of its salts. With tannic acid morphia affords a copious white precipitate. It is capable of neutralizing the strongest acids, and of forming with them compounds which are soluble and crystallizable.

5420. Agreeably to the late observations of Larocque and Thibierge, the perchloride of gold produces with morphia a precipitate which is at first yellow, next bluish, and lastly violet. In the state in which it assumes the colour last mentioned, the gold is revived; while the precipitate, of which it forms a part, becomes insoluble in water, alcohol, caustic alkalies, or in sulphuric, nitric, or chlorohydric acids. Yet with aqua regia, it makes a solution which is precipitated by the green sulphate of iron.

5421. With the oxacids, with organic acids, and with the halogen bodies, morphia generates salts which are capable of crystallization and of being dissolved by water. The medicinal properties of the alkali are not impaired by these combinations. In this country the sulphate is the most used; but Dr. Kane alleges the "*muriate*" to be the most important compound of morphia.

#### *Of Paramorphia, or Thebaine.*

5422. *Paramorphia* is an alkali lately discovered by Pelletier in minute proportion in opium. It is identical with morphia in composition, but quite distinct in its properties. It is, therefore, *isomeric* with morphia, and hence its name.

5423. *Paramorphia* is white, scarcely soluble in water, of an acrid and styptic, rather than a bitter taste, and very soluble in alcohol or ether, even when cold, and still more so when hot. It differs from morphia in not being reddened by nitric acid, in not forming crystallizable salts with acids, and in not striking a blue colour with the salts of iron. It also differs from morphia in its action on the system, producing *tetanic* symptoms in doses of a grain.

5424. *Pseudomorphia* is a name given to another alkali discovered by the same distinguished chemist in opium, likewise in minute proportion. It resembles morphia in the characteristic properties of becoming red with nitric acid, and of striking a blue colour with the salts of iron, and yet differs from it in *not being poisonous*. It is not always present in opium, and the circumstances under which it is produced are not known.

*Of Codeia, or Codeine.*

5425. This vegetable alkali was discovered in 1832, by Lobiquet. It exists in opium as a meconate. It is in the form of colourless crystals, which are soluble in two parts of boiling water, also soluble in alcohol and ether, but insoluble in alkaline solutions. Its capacity of saturation is very nearly the same as that of morphia; but it may be distinguished from that alkali by the different form of its crystals, by its greater solubility in water, and by its insolubility in alkaline solutions. It has a decided action on the animal economy, producing first excitation, and afterwards depression.

*Of Narcotina, or Narcotine.*

5426. In order to obtain narcotina, opium may be comminuted, and digested with as much ether as will cover it, at a temperature near the boiling point of the ether, for three or four days. The ether being decanted and allowed to evaporate, the narcotina will appear in slender prismatic crystals, soiled by caoutchouc, resin, and colouring matter. Being subjected to boiling alcohol and recrystallized by refrigeration therefrom, they are rendered purer, and further purified by repeated solution and recrystallization. To remove all the narcotina, opium must be subjected to successive portions of ether.

*Of Narceia, or Narceine.*

5427. This alkali was discovered in opium by Pelletier in 1832. It exists in white, silky, acicular crystals, inodorous, of a slightly bitter taste, sparingly soluble in water, more soluble in alcohol, and insoluble in ether. It is rendered blue by the dilute mineral acids, but does not, like morphia, become blue with the salts of iron, nor red with nitric acid.

*Of Quinia, or Quinine.*

5428. In the various kinds of cinchonia, known in commerce as Peruvian bark, there are three organic alkalies, quinia, cinchonia, and aricina, of which the most important is that which bears the name at the head of this paragraph. Quinia is generally procured from yellow bark. The process usually employed for its elaboration is as follows. The bark, coarsely powdered, is boiled with sul-

phuric or chlorohydric acid. In the case of sulphuric acid, the proportions given are three fluid drachms to a gallon of water; in the other case, two of acid to ten of water; a pound of bark being employed.

5429. The bark is to be subsequently exposed to a similar ordeal with a half, and with a fourth part of the quantity of acid at first employed. To the united solutions, strained and cooled, add hydrate of lime till there be an alkaline reaction. The precipitate is to be collected. This, when sulphuric acid is used, will consist in part of sulphate of lime; but when the other solvent is used, the lime will remain in solution in the state of chloride. In either state, the precipitate being digested in alcohol, the alkali is taken up. The solution thus formed, is subjected to distillation with water. The residue being treated with sulphuric acid in excess, on evaporation affords crystals of sulphate of quinia; the sulphate of cinchonia remaining in solution. From the sulphate, pure quinia may be obtained by adding to a solution of it caustic potash, also in solution, drying the resulting precipitate, dissolving it in a quantity of alcohol, as small as possible, and allowing the liquid thus obtained to evaporate leisurely in a place moderately warm. Under these circumstances, quinia crystallizes in union with an atom of water, forming of course a crystalline hydrate. This water it loses by fusion. Quinia is intensely bitter. It requires for solution, two hundred parts of hot water, and is almost insoluble in cold water. In alcohol or ether it dissolves readily. The salts of this alkali are soluble in water, as well as in alcohol, and are capable of crystallizing. In common with those of other alkalies, and of ammonia, the oxysalts which it forms, require an atom of water, as already mentioned (5406).

5430. *Of the Chlorohyduret or Muriate of Quinia.* This salt forms pearly crystalline needles, which are very soluble in water. It acts as a base with chloroplatinic, or chlorohydrargyric acid (corrosive sublimate), forming what are called double salts by some chemists, but which I conceive should be called, severally, chloroplatinate or chlorohydrargyrate of the chlorohyduret of quinia; or for the sake of brevity, as in other cases, simply a chloroplatinate of morphia, or chlorohydrargyrate of quinia (5406).

5431. *Basic Sulphate of Quinia* consists of two atoms

f quinine, one of sulphuric acid, and eight of water; its formula being  $\text{Qu So}^3 8\text{HO}$ . The manufacture of this compound is conducted on a large scale, according to the process above given for the extrication of quinine, and various other methods. In crystallizing, this sulphate enters into combination with six atoms of water of crystallization, and two acting as a base. Hence in dry air, or when gently heated, it relinquishes six, yet retains two, which cannot be expelled without partial decomposition. This salt is but sparingly soluble in water, requiring thirty parts at a boiling heat, and seven hundred and forty in the cold. In alcohol, unaided by heat, it requires eighty parts for solution; but much less at the temperature of ebullition. Its crystals are small pearly plates or needles, which, when heated, fuse, and phosphoresce vividly, being totally decomposed at a high temperature.

**5432. Neutral Sulphate of Quinia.**—This salt crystallizes in rectangular prisms, of which the formula is  $\text{Qu So}^3 \text{HO}$ . They are prone to effloresce, dissolve in ten parts of water at  $60^\circ$ , and undergo aqueous fusion at  $112^\circ$ . This sulphate is very soluble in alcohol, and, though from its constitution it should be neutral, reddens litmus.

**5433. Basic Sulphate of Quinia of Commerce.**—In the state in which basic sulphate of quinia is sold in commerce, under the name of sulphate, it is sometimes adulterated with boric acid and with sulphate of lime. These substances may be detected by exposing the aggregate to red heat, by which the elements of the sulphate may be dissipated, and the adulterations exposed to view. Sugar and margaric acid have also been used as adulterations. If these, the latter may be detected by its insolubility in diluted acids, the former by washing a sample in water, and adding carbonate of soda to precipitate the quinia, when the sweet taste of the sugar will become perceptible.

**5434. Phosphate of Quinia** crystallizes in small, but brilliant needles, soluble both in water and in alcohol.

**5435. Ferropurssiate, or Cyanoferrite, of Quinia** is formed by boiling one part sulphate of quinia, and one and a half of cyanoferrite of potassium, in seven of water. The generated salt separates as greenish yellow, oily substance. The mother liquor being decanted when cold, the cyanoferrite is to be redissolved in boiling alcohol, whence on refrigeration it crystallizes in greenish yellow needles.

*On the Reaction of Chlorine with Quinia and its Salts.*

5436. If sulphate of quinia be made to form a dilute solution with water, impregnated with chlorine, and liquid ammonia be added, a green precipitate ensues, the liquid assuming an intensely green colour. The precipitated substance has been called dalleiochin. If the residual green liquid be evaporated with access of air, it changes to dark red, while sal ammoniac is generated, and two bodies, of which only one is soluble in alcohol. The soluble body is called rusiochin, the other, melanochin. Kane's Elements.

*Of Cinchonia, or Cinchonine.*

5437. This alkali abounds in the gray bark (*cinchona micrantha*) from which it may be extricated by means analogous to those employed in the case of quinia. Usually it is obtained from the mother waters of the sulphate of the alkali last mentioned, by saturating the excess of acid by which it is retained in solution during the crystallization of the sulphate of quinia. Under these circumstances, being precipitated by an alkaline base, and afterwards redissolved by alcohol, it is obtained in thin, colourless, prismatic crystals, by vaporizing this solvent. Its taste is peculiar, as well as bitter. Boiling water only takes up  $\frac{1}{150}$  part; but it readily dissolves in alcohol and ether. It fuses at  $330^{\circ}$  without loss. Between its salts and those of quinia, there is a great resemblance.

5438. *The chlorohydruret of cinchonia* crystallizes in brilliant interwoven needles, and like the congenerous compound of quinia (5389) acts as a base with electronegative chlorides, such as chloroplatinic, and chlorohydrargyric acid.

5439. *Basic sulphate of cinchonia*,  $C^2 + SO^3$  forms rhombic prismatic crystals, which require for solution 54 parts of water. The neutral sulphate holding only half as much base, is more soluble, crystallizing in large well formed rhombic octohedrons.

*Of Aricina, or Aricine.*

5440. This alkali was discovered in 1829 by Pelleter and Coriol, in a bark brought from *Arica*, on the Pacific



coast of South America, which was fraudulently mixed with the Calisaya bark. It is a white, transparent, crystalline substance, having a warm and intensely bitter taste, which is long in developing itself. It dissolves in alcohol and ether, but is completely insoluble in water. By nitric acid it is coloured green. The salts agree in their properties with those of quinia and cinchonia.

### *Of Strychnia, or Strychnine.*

5441. The poisonous principle of the *Strychnos nuxvomica*, and *Strychnos ignatia* or *colubrina*, is considered as an alkali, and called strychnia. It may be developed by a process similar to that used for morphia. It was originally obtained by Pelletier and Caventou, by subjecting the bean of the *strychnos ignatia*, duly rasped, to nitric ether in a Papin's digester, to remove fatty matter; and subsequent exposure of the residue to alcohol, in which the strychnia, in union with an acid, dissolves. The alcohol having been evaporated, and the residuum dissolved in water, the addition of potash caused the alkali to precipitate. It was afterwards washed in cold water, and redissolved in alcohol, from which it crystallized by evaporation.

5442. The colour of strychnia is white. Its taste is intolerably bitter, leaving a metallic impression in the mouth. It is nearly insoluble in water, or ether, but is very soluble in alcohol. It is a terrible poison, very small quantities producing tetanus to a fatal extent; being used by the natives of Borneo to render their arrows poisonous, under the names either of *upas tieuta*, or *woorara*.

### *Of Brucia, or Brucine.*

5443. This alkali exists in the bark of the *Brucia anti-dysenterica*, or false *angustura*. The bark was first subjected to sulphuric ether, and afterwards to alcohol. The alcohol being evaporated, afforded a dry residuum, which was dissolved in water. The solution in water was saturated with oxalic acid, and evaporated to dryness. An oxalate of brucia resulted, which, after being depurated by alcohol of colouring matter, with which it was associated and disguised, was decomposed by lime or magnesia. As either of these bases forms an insoluble salt with oxalic

acid, while brucia is soluble in 500 times its weight of boiling water, or in 850 parts of cold, it was separated from the insoluble oxalate by water.

5444. Brucia crystallizes in oblique prisms, with parallelograms for their bases. It is less bitter than strychnia, but its taste is more acrid and durable. It melts when heated a little above  $212^{\circ}$ , and congeals on cooling into a mass resembling wax. It neutralizes acids, affording a distinct class of salts. On animals, its effects are analogous to those of strychnia, but less violent.\*

### *Of Delphia, or Delphine.*

5445. It was in the seeds of the *Delphinium staphisgria*, or stavesacre, in which it exists as a malate, that this alkali was detected. A decoction of the seeds, which had been cleansed and reduced to a pulp, was filtered. The fluid, which passed the filter, was boiled with magnesia, which liberated the delphia. It was then separated from the magnesia by alcohol, and from this solvent by evaporation.

5446. Delphia is white, pulverulent, and very soluble in alcohol and ether. It is inodorous, but its taste is extremely acrid and bitter. Water derives from it an acrid taste, though it does not dissolve any appreciable quantity. By combination with acids, it forms neutral salts, which are soluble in water, and very acrid and bitter.

5447. Concentrated sulphuric acid reddens, and afterwards carbonizes delphia. Chlorine renders it green. Courbe alleges that stavesacre contains, in addition to that which has been described, a yellow, resinous substance, of which the formula is  $C^{32} H^{23} O^4 N$ ; and the name suggested for it is staphysain. This is distinguished by insolubility in ether, or water; and solubility in dilute acids, without neutralizing them.

\* Mr. Fuch advances that brucia is a combination of strychnia with a resin which this last mentioned substance holds obstinately, and which has the property of being reddened by nitric acid. It is to this impurity that brucia owes its liability to be made red by the acid above mentioned. Mr. Fuch has found a method of separating this resin from brucia, and consequently of converting this supposed peculiar alkali into strychnia. He has not, however, succeeded in causing strychnia to combine with the resin in question so as to form brucia. Although Mr. Fuch mentioned it to be his intention to publish his process for the depuration of brucia, a year has elapsed without any further information having been promulgated by him on this subject. Berzelius' Report for 1841, p. 141.

*Of Veratria, or Veratrine.*

5448. Veratria is an alkali obtained from the seed of the *Veratrum sabadilla*; also from the roots of the *Veratrum album* (white hellebore), and *Colchicum autumnale* (meadow saffron).

5449. The seeds, partially depurated by digestion with ether, yielded a coloured tincture with heated alcohol. This tincture deposited some waxy matter on cooling, and by evaporation afforded a residuum, soluble in water, excepting a small portion of extraneous matter. The watery solution being slowly and partially evaporated, until an orange-coloured precipitate ceased to appear, acetate of lead was added to it. A copious yellow precipitate ensued, and the liquor, being separated from it by a filter, became almost colourless. This fluid was subjected to sulphydric acid, to precipitate any lead which it might contain. The solution then gave, with magnesia, a precipitate, from which alcohol took up veratria. From the alcoholic solution, the veratria was afterwards isolated by evaporation.

5450. Veratria is white, pulverulent, and inodorous, but, nevertheless, poisonous when inhaled, producing violent and dangerous sneezing. Its taste is not bitter, but excessively acrid. It reacts like an alkali, is insoluble in water, but very soluble in alcohol and ether. It melts at 30°. Its salts are for the most part crystallizable and neutral, but decomposable by water into free acid, and a basic salt. Taken into the stomach in minute quantities, produces intolerable nausea and vomiting, and in large doses, death.

*Of Sabadilla.*

5451. Sabadilla was discovered by Couerbe, as an alkali accompanying *veratria* in *veratrum sabadilla*, and in the roots of the *Veratrum album* (white hellebore), and *Colchicum autumnale* (meadow saffron).

5452. By boiling the precipitate, obtained by carbonate of soda from an infusion of sabadilla seeds in diluted sulphuric acid, sabadilla may be separated in radiated needles, of a pale rose colour, which may be rendered white by dehydration. This alkali is a white, crystallizable substance,

insupportably acrid, fusible by heat, readily soluble in hot water, very soluble in alcohol, and wholly insoluble in ether.

*Of Jervina, or Jervine.*

5453. Jervina is found in veratrum album, associated with veratrine, from which the sparing solubility of its sulphate, and its readiness to crystallize from an alcoholic solution with four atoms of water, renders it liable to be separated. Jervina, when pure, is white, easily fusible, decomposable at  $400^{\circ}$ , nearly insoluble in water, but copiously soluble in alcohol. Of its salts, the acetate readily dissolves in water, although in this liquid its sulphate, nitrate and chloride, are sparingly soluble. The chloride of jervina unites with chloroplatinic acid. Kane, 1069.

*Of Colchicina, or Colchicine.*

5454. Colchicina is a vegeto-alkali existing in the seed of the meadow saffron (*Colchicum autumnale*).

5455. It may be extricated by the following process. Digest the seeds in a mixture of sulphuric acid and weak alcohol; neutralize the excess of acid by lime, remove the alcohol by distillation, decompose the residual liquor by carbonate of potash in excess, dissolve the washed and dried precipitate in absolute alcohol, decolorize the solution by animal charcoal, add a few drops of water, and evaporate it until the colchicina crystallizes in colourless needles.

5456. This alkali is intensely bitter, but not so biting to the taste as veratrine, nor is it productive of violent sneezing. It is moderately soluble in water, very soluble in alcohol, or ether. Though but feebly alkaline in its reaction in other respects it neutralizes acids thoroughly. By tincture of iodine it is precipitated of a rich orange colour, by nitric acid it is coloured dark violet blue. Though most abundant in the seeds, it pervades all parts of *colchicum*. Kane, 1069.

*Of Emetia, or Emetine.*

5457. This alkali is obtained from ipecacuanha. The roots, well pulverized, are digested in ether. They are then subjected to alcohol, the resulting solution is evaporated, and the residuum dissolved in water, and macerated upon magnesia, which causes the emetia to precipitate.

This precipitate is washed with cold water to remove colouring matter, and afterwards subjected to alcohol, which takes up the emetia. The emetine again separated from its solvent by evaporation, being dissolved by diluted acid, and blanched by animal charcoal, may be precipitated pure by any of the alkaline oxides.

5458. Thus obtained, emetia is white, pulverulent, and unalterable by the air, scarcely soluble in water, but very soluble in ether or alcohol. Its taste is slightly bitter. It possesses strong alkaline properties, restoring the colour of litmus, when reddened by an acid. It is capable of forming salts, which, though neutral, are not crystallizable. It appears to possess all the emetic properties of the root from which it is procured.

*Of Solania, or Solanine.*

5459. Solania is the name which has been given to an alkali which exists in the black nightshade (*solanum nigrum*), and in the bittersweet (*solanum dulcamara*), also in the shoots of the *solanum tuberosum*, or potato.

5460. The filtrated juice of the berries of the nightshade being digested in ammonia, the resulting precipitate is washed on the filter, and digested in boiling alcohol. After the evaporation of this fluid, solania is obtained in sufficient purity. It is a white, opaque, pearly powder, which is inodorous, slightly bitter, and nauseous. Its acid solutions are more bitter. Its salts, though neutral, are uncrystallizable. In cold water it is insoluble, and in hot dissolves only to a small extent. It is very soluble in alcohol, but is not dissolved by ether. It restores the colour of litmus, reddened by an acid. It causes vomiting at first, afterwards sleep, or death, according to the dose, being a strong narcotic poison. With salts of emetine, tannic acid, or corrosive sublimate, it produces white precipitates; with iodine and chloroplatinic acid, brownish yellow precipitates. According to Kane, the injurious properties of unripe potatoes result from the presence of this body. It exists abundantly in the early shoots (underground) and buds of the tubers.

*Of Caffein or Caffea,\* or Theine.*

5461. It seems hardly credible that there should be a crystallized nitrogenated principle common both to tea and to coffee. Yet, agreeably to analyses recently made, the substances which had been discovered in tea and coffee, and called theine, or caffein, are identical in composition and properties.

5462. Moreover, a principle elaborated from guaran, a paste made from the seeds of paullinia sorbilis, is alleged by Martius to be identical in composition with caffein, and to be a base in its properties.

5463. To extract caffeia, the raw coffee seeds, well dried and pulverized, are to be exhausted by boiling water. In the next place subacetate of lead must be added to the resulting solution. This is to be filtered afterwards, and any excess of lead precipitated by sulphydric acid. After a second filtration, the solution being concentrated sufficiently by evaporation, the caffeia crystallizes on cooling. Re-solution, and recrystallization are requisite to render it pure.

5464. Caffea may also be extricated from a filtered decoction of tea leaves: hence its other name, theine.

5465. Caffea assumes the form and appearance of needles, having a silky lustre. It is feebly bitter, sparingly soluble in ether, cold water, or alcohol. At  $212^{\circ}$  it loses eight per cent. of water. It fuses at  $352^{\circ}$ , and sublimes at  $725^{\circ}$ . From its solution it may be thrown down by tannic acid. Boiled with caustic potash, or baryta, caffeia is resolved into ammonia, cyanuric, formic, and carbonic acids. With sulphuric or chlorohydric acid it forms crystalline compounds. Its composition, according to Liebig, is represented by the formula above given.

5466. Graham alleges that the active properties of tea and coffee are not due to caffeia; but it is admitted that no other vegetable substance contains so large a propor-

\* Caffea is one of the crystalline organic principles which it is difficult to name or to classify, on account of the discordancy of the authorities which bear upon the question. Heretofore it has been placed among the neutral principles, and in the United States Dispensatory, and in the recent works of Kane, Graham and Gregory, has been treated of as such, and called caffeia. But in the report of Berzelius for 1841, it is mentioned that Martius has found it to be identical with guaran, an organic base, elaborated from the seeds of paullinia sorbilis. Accordingly it is placed by Berzelius, in his list of contents, under the head of vegetable bases, with morphine, brucia, &c. But while Martius and Berzelius assign to it the rank of an alkali, they do not change the terminating monosyllable, as the continental chemists have not adopted the termination in *a* for alkaline bases.

tion of nitrogen, and Liebig remarks that  $2\frac{1}{16}$  grains of **caffea** may furnish all the nitrogen required by an ounce of human bile. This fact naturally suggests that tea and **coffee** may be serviceable in furnishing nitrogen for biliary and other secretions, in beings whose habits of life do not make it healthful or agreeable to consume a sufficient quantity of bread and meat to supply all the nitrogen necessary to the vital functions.

5467. According to this view of the subject, it is remarkable, that civilized nations, comprising a majority of mankind, should in modern times have been led, as it would seem, intuitively, to resort to two sources, apparently so different, as the tea leaf and coffee berry, for the same preëminently nitrogenated principle as an almost indispensable article of daily food.

*“Chelerythrina, or Chelerythrine.*

5468. “This substance is extracted from the roots of the **chelidonium majus**, by digestion with dilute sulphuric acid. The liquor so obtained is to be evaporated and mixed with ammonia. The brown precipitate which falls is to be washed, pressed between folds of paper, and digested in alcohol, with some sulphuric acid. The alcoholic solution being mixed with water, and the spirit distilled off, the residual liquor is precipitated by ammonia, and the precipitate being washed and dried by pressure, is to be digested in ether, and the ethereal solution evaporated to dryness. The mass so obtained is then digested in dilute muriatic acid, which leaves a resinous substance undissolved. The deep red liquor evaporated to dryness, and washed with ether, leaves a mixture of muriate of chelerythrine and muriate of cheledonine; the former of which is dissolved by washing with a small quantity of water, whilst the latter remains undissolved.”

5469. “From the solution of the muriate, the chelerythrine is precipitated by ammonia, as a white curdy powder. From its ethereal solution it remains as a resinous mass, which remains soft for a long time; it is insoluble in water; its solutions in alcohol and ether are pale yellow. With acids it forms salts of a rich crimson colour, which generally crystallize. Tannic acid produces in their solutions a precipitate soluble in alcohol.” Verbatim from Kane, 1070.

*"Chelidonia, or Chelidonine.*

5470. "The preparation of this substance has been in great part described in the preceding article. By digesting the sparingly soluble muriate with ammonia, then dissolving in sulphuric acid and precipitating with muriatic acid, it is freed from all traces of chelerythrine, and finally the pure chelidonine, separated by ammonia, is dissolved in boiling alcohol, from which it crystallizes, on cooling, in brilliant colourless tables. It is insoluble in water, soluble in alcohol and ether; it tastes bitter, and reacts alkaline; its salts are colourless, and those with the mineral acids crystallize; its solutions give with tannic acid a precipitate." Verbatim from Kane, 1071.

*Of Atropia, or Atropine.*

5471. Atropia is procured from a decoction of the leaves of the *Atropa belladonna*, or deadly nightshade. Two pounds of the leaves were boiled in successive portions of water, which being united, and sulphuric acid added to the whole, the resulting liquid was filtered, and yielded a crystalline precipitate with potash. This precipitate, repeatedly dissolved in acids, and precipitated by alkalis, gave pure atropia. Thus obtained, it is snow white, and quite tasteless. When recently precipitated, it is slightly soluble in water. After being dried, it is insoluble in water, ether, or oil of turpentine. In cold alcohol it is sparingly soluble; but copiously in the same menstruum when boiling hot.

5472. Atropia forms compounds with acids, which cannot, however, be rendered so neutral, as not to indicate acidity.

*Of Aconitia, or Aconitine.*

5473. The fresh expressed juice of the monkhood, *aconitum napellus*, being boiled and filtered, the resulting liquor, subjected to an excess of carbonate of potash, is to be agitated with ether so long as it takes up any thing. On vaporizing the ether, aconitia is deposited. From the dry plant, or its seeds, a solution of aconitia may be obtained by water holding an ounce of sulphuric acid to each pound. This may be decomposed by carbonate



and the alkali extricated from the resulting precipitate by ether or alcohol. Aconitia crystallizes from an etheral or alcoholic solution, partly in white grains, but the most part forms a colourless vitreous-looking mass. It has a sharp bitter taste, and is intensely poisonous. It is soluble of neutralizing the most powerful acids. Its solution gives a white precipitate with alkalies proper, or chloride of gold; with iodine an orange precipitate.

*Of Belladonia, or Belladonine.*

1. This alkali is obtained by subjecting the dried belladonna to distillation with a solution of caustic alkali, precipitating from the liquid which comes over, with alkali with which it is accompanied, by chloroplatinic acid, and heating the washed precipitate with carbonate of potash. The belladonia being sublimed, condenses in thin, rectangular, prismatic crystals. Belladonia, isolated, has a penetrating odour resembling that of ammonia, and forms a solution with water, which reacts as if of an alkali. It is not very poisonous. Its salts are very soluble like the corresponding ammoniacal salts.

*Of Daturia, or Daturine.*

2. The seeds of the datura stramonium, vulgarly known as the thorn apple, Jamestown, or jimson weed, contain a saline principle to which the name at the head of this article is given. It is to this, that the efficacy of the tincture constituted by the inspissated juice, and the well known poisonous property of the plant, are due.

3. Agreeably to the process of Brandes, who first prepared daturia, the seeds are to be boiled in alcohol, and ammonia being added, the resulting precipitate is to be dissolved by the same liquid. According to Kane, it is obtained by the same processes as aconitia, above mentioned.

4. From its solution in spirit, it crystallizes in very small groups of needles. It is quite inodorous when pure, although the juice of the plant smells disgustingly of tobacco. Its solution, it requires 72 parts of boiling water, 250 of cold water, 21 parts of ether, and 3 of alcohol. It fuses at 212°, and at a higher temperature volatilizes, un-

changed, in white clouds. It reacts like an alkali, and is capable of forming, with acids, crystallizable salts, which are highly poisonous. In its habitudes with reagents, it resembles atropia.

*Of Conina, or Coneine.*

5478. This alkali exists in all parts of the hemlock (*conium maculatum*), especially in the seeds, from which it may be extricated by the following means:—They are to be bruised, and being mingled with one part of a concentrated solution of potash, and eight of water, are to be subjected to the distillatory process till the water, which distills, becomes inodorous. The distilled solution, after being neutralized by sulphuric acid, must be evaporated to the consistency of a syrup; and being, in this state, treated two or three times with a mixture of one part of ether, and two of alcohol of 820°, the coneine is taken up. Some water being added, the ether and alcohol are removed by distillation, and the residual water by evaporation. The dried residuum is to be mingled with half its weight of a concentrated solution of caustic potash, and subjected to distillation with a receiver carefully refrigerated. The oil portion must be separated from the aqueous portion of the liquid which comes over, and this last again distilled from hydrate of lime. From any ammonia with which it may be associated, the coneine may be freed by exposure for a few hours in vacuo, over sulphuric acid.

5479. Pure coneine is extremely poisonous, existing in the form of a colourless transparent liquid, of the density 0.890. Its taste is disgustingly sharp, its smell highly nauseous and pungent, somewhat like that of the plant. It is soluble in 100 parts of cold water, which becomes turbid by being heated; but four parts of coneine dissolve one of water, forming a solution which may be rendered turbid by the heat of the hand. With alcohol, ether, and oils, it mingles in all proportions. It distills, per se, at 370°, but requires less heat when associated with the steam of boiling water. It reacts like an alkali with the assistance of water, but not when anhydrous. It is capable of saturating acids completely, having the least atomic weight of any known organic alkali. Its salts, which crystallize imperfectly, are decomposed by much water. In alcohol or a mixture of this solvent with ether, they readily dis-

olve, but are insoluble in pure ether. The precipitate given by their aqueous solutions with iodine is saffron yellow; that yielded with tannic acid, white.

5480. Coneia is coloured blood-red by nitric acid. By exposure to air it turns brown, and is resolved into ammonia, and a bitter, inodorous, resinous substance, which is not poisonous.

### *Of Nicotina or Nicotine.*

5481. The preceding name is given to the active poisonous principle, to which tobacco (*nicotiana tabacum*) and some other plants owe their active qualities. For its elaboration, the means described as suitable for the elaboration of coneia may be used, though in either case magnesia, or any other alkaline earth, or alkali, might be substituted for potash in the first step of the process.

5482. Pure nicotina or nicotine is a colourless oily liquid, endowed, in a high degree, with the odour and taste of tobacco. It is soluble in water in all proportions, which is a property displayed by no other organic base. It is also soluble in ether or alcohol. When anhydrous, it emits white fumes at  $212^{\circ}$ , and at  $480^{\circ}$  distils, undergoing, however, a partial decomposition. Its distillation is accomplished easily with the aid of water.

5483. Nicotina is highly alkaline, neutralizing and forming soluble salts with acids. Of these, some are crystallizable, retaining, however, the savour of tobacco. Subjected to alkalies, they evolve the characteristic odour of the plant.\*

5484. *Of Lobelina or Lobeline.*—It appears by an article in the American Journal of Pharmacy for April, 1841, Vol. 1, that Mr. Procter, jr., has obtained an organic alkali from the seeds of the *lobelia inflata*, by acidulated alcohol, displacement, ether, and evaporation. This alkali is repre-

\* A new process for the evolution of nicotina is given in the *Journal de Pharmacie*, for February, 1842, of which the steps are as follows:—Maceration for 24 hours in water acidulated by sulphuric acid; expression, evaporation to a syrupy consistency; distillation with potash, water being added to prevent injurious concentration; neutralization by oxalic acid; evaporation to dryness; treatment with absolute alcohol, which takes up oxalate of nicotina; evaporation, decomposition by potash; solution in ether; evaporation, whence results nicotina free from all impurity, excepting tar and alcohol in a minute proportion. Agreeably to M. V. Ortigosa, the author of this new process, nicotina forms compounds with chloroplatinic, and chlorohydrate acid.

sented as having a great resemblance to nicotina, but as much less poisonous.

*Picrotoxine or Picrotoxia.*

5485. The extremely poisonous principle of *cocculus indicus* has received the name of picrotoxine, but has not been conceived to have basic properties, nor to agree with the organic alkalis in holding nitrogen as an element. Nevertheless, in the late work of Liebig and Gregory, 1168, it is arranged among the organic bases, and is alleged to have been shown, by the recent researches of Mr. Francis, to contain 1.38 per cent. of nitrogen. Yet a new formula for picrotoxine had not been published by that chemist.

5486. I subjoin an account of the process for obtaining this alkali, and a description of its properties.

5487. The bruised *cocculus indicus*, after being subjected to pressure in order to expel as much as possible of their fat oil, are boiled in alcohol. The alcohol being separated from the matter which it takes up by distillation, this matter is redissolved in boiling water, slightly acidulated. From the resulting solution, on cooling, the picrotoxine separates in short, thin, colourless prisms, insusceptible of fusion. Picrotoxine is soluble in twenty-five parts of boiling water, and very soluble in alcohol. It is intensely bitter, and highly poisonous. Its formula is probably  $C^{12} H^7 O^5 N$ .

*Of Antiarine or Antiaria.*

5488. The deadly poison to which the name of antiarine has been given, is in a predicament analogous to that in which picrotoxine has heretofore been placed. I mean that of resembling many of the organic bases in its activity as a poison, while devoid of nitrogen, and of the ability to react like a base. It is not, however, improbable, that further researches may prove the pretensions of antiarine to rank with the organic alkalis, both as to properties and composition. Antiarine is the active principle of that most deadly upas poison, respecting which, highly exaggerated accounts were published about forty years ago, representing that the tree producing it could not, without loss of life, be approached, unless upon the wind-

ard side. Its formula is alleged to be  $C^{19}H^{10}O^5$ . It crystallizes in small scaly crystals, soluble in 250 parts of cold water, 70 of alcohol, and 2790 of ether.

*Bases from the Oil of Mustard.*

**5489. Thiosinnamina.**—When the oil of mustard is brought in contact with three or four times its volume of strong ammonia, crystals are formed, which are purified by recrystallization. These are thiosinnamina: formula,  $H^8N^2S^2$ .

**5490. Thiosinnamina** is soluble in hot water, less so in cold water, soluble in alcohol and ether. It has a bitter taste, and no smell. At  $392^\circ$  it is resolved into ammonia, and a resinoid basic compound not fully investigated. Thiosinnamina combines with acids, but its salts do not crystallize: it yields a chloroplatinate with chloroplatinic acid  $= C^8H^8N^2S^2HC\ Cl + Pt\ Cl$ ; and with corrosive sublimate a chlorohydrargyrate  $= C^4H^4NS\ Cl + Hg\ Cl$ .

**5491. Sinnamina.**—This new base is obtained in the following way:—Thiosinnamina is digested with moist hydrated protoxide of lead till all the sulphur is removed. The residue is then subjected to water, finally to alcohol. The resulting solution is evaporated to a syrup, which, after some time, deposits fine transparent crystals of sinnamina.

**5492. Sinnamina** is a powerful base, expelling ammonia from its salts, and precipitating the solutions of peroxide of iron, of copper, and of lead. It combines with acids, but yields no crystallizable salts. It is precipitated by chloroplatinic and chlorohydrargyric acid, and throws down silver from its solution in nitric acid. When heated, it evolves ammonia, and leaves a basic resinoid matter. The production of sinnamina from thiosinnamina is effected by the separation of all the sulphur with more or less hydrogen. I say *more or less*, since it is not known with certainty whether the formula of sinnamina is  $C^8H^6N^2$  or  $C^8H^3N^2$ . (Varrentrapp and Will.)

**5493. Sinapolina.**—This compound, discovered by Simon, is obtained by depriving oil of mustard of its sulphur, by the action of baryta or of oxide of lead. It is soluble in hot water and alcohol, and crystallizes in shining, fatty, fusible scales. Its solution has an alkaline action. It combines with acids, and may be separated

from them by ammonia. When combined with chlorohydric acid, it precipitates the chloroplatinic and chlorohydrargyric acids. It is generated from the oil of mustard by the abstraction of two atoms of bisulphuret of carbon, and the addition of two atoms of water. Thus  $C^{16} H^{20} N^1 S^4 + 2HO = C^{14} H^{12} N^2 O^2 + 2CS^2$ . The formula of *sina-polina* is  $C^{14} H^{12} N^2 O^2$ . Liebig and Gregory, 1156.

5494. *Cinchovine* is the name given by Manzini to a new alkali which he has extricated from a species of Peruvian bark, "*cinchona ovata*." It is obtained by a process analogous to that usually employed to obtain quina. No statement is made respecting its efficacy. On this account, and because of the alleged inefficacy of the species of cinchona, from which it is derived, it may be inferred that cinchovine has little or no practical value, and will not merit that more should be said of it here. *Comptes Rendu*, 25, 125.

5495. *Of Cisampelina or Cisampeline*, also called pelosine. In his Report on Chemistry for 1841, Berzelius gives the following information respecting this base, lately discovered by Wiggers. A filtered solution of the roots of *cisampelos pareira*, obtained by digestion in water acidulated by sulphuric acid, is saturated with carbonate of soda, avoiding to add an excess. The precipitate twice washed, and well dried by filtering paper, and subsequent exposure to a heat of  $212^\circ$ , is subjected to pure ether. Being taken up by this solvent, it is recovered from it pure and anhydrous by the distillatory process.

5496. *Cisampelina*, thus procured, is hard and brittle, and to the taste, sweetish bitter and nauseous. It has not been crystallized. It is to this principle that the medicinal properties of the *cisampelos pareira* are ascribed. The alkali is called pelosine by Wiggers, its discoverer; but I concur with Berzelius, that the other appellation is preferable as recalling the idea of its source.

5497. *Of Hederina, Surinamina, and Jamaicina*.—In 1824, Mr. Hutten-schmidt alleged that he had discovered two bases in the "*cortex geoffrium jamaicensis* and *surinamensis*." Agreeably to Berzelius' report, the existence of these bases has lately been confirmed by Wiggers. Vandamme and Chevalier, according to the same authority, have discovered a base in *hedera helix*. As no important efficacy is ascribed to these bases, I do not deem it necessary to notice them further. The same considerations have prevented me from noticing some other bases, of which accounts are to be found in the reports of the great Swedish chemist; and likewise melamine and ammeline, derived from melam, a product of the decomposition of sulphocyanide of potassium.

*Of certain general characteristics of the Vegetable Alkalies distinguishing them from Inorganic Bases, and of those which distinguish them into several different sets.*

5498. It is observed by Liebig and Gregory, that the organic bases require less acid for saturation in proportion as they contain more oxygen; although it is well known, that the more the oxygen in an inorganic base, the greater the quantity of acid which its saturation requires.

5499. Agreeably to the same authority, the salts formed with aconita, atropia, brucia, cinchonia, codeia, conicina, delphinina, emetia, morphia, narcotia, quinia, strychnia, veratria, are precipitated white by an infusion of galls. The precipitate is a tannate, which, by exposure to the air, becomes converted into a soluble gallate.\*

5500. I will here quote from Liebig and Gregory the following arrangement of the alkalies, as I consider such generalization always instructive, and serviceable to the memory.

1. *Volatile bases containing no oxygen.*

These are anilina and nicotina, to which may be added conicina, although it is not certain that this base is destitute of oxygen.

2. *Bases derived from the oil of mustard.*

These are thiosinamina, sinamina, and sinapolina.

3. *Bases of cinchona bark.*

These are quinia, cinchonia, and aricina.

4. *Bases of the papaveraceæ, or the various species of poppy.*

These are morphia, codeia, narcotina, thebaina, pseudomorphia, narceia, and chelidonia.

5. *Bases found in the solanaceæ, strychnaceæ, and other plants of the same kind.*

These are atropia, solania, jervina, brucia, strychnia, sabadillia, veratria, delphia, staphisia, menispermia, picrotoxia, emetia, corydalina, berbina, piperina, harmalina, caffeia, and theobromia.

5501. I have pointed out the inconsistency of supposing (5406), that when chlorohydric acid combines with an organic alkali, it can form a combination meriting to be called a chlorohydrate, while the compound which is engendered by the contact of this acid with ammonia is supposed to be *ammonium*; in other words, a *chloride of the hydruret* of that gaseous body. On the subject of iodine, Berzelius has urged that "*a direct combination of it with a vegetable alkali is as unlikely to exist, as would be a like combination with any other salifiable base; and, moreover, experience shows, that such compounds are neither iodates, nor iodohydrates of the vegetable alkali.*"

5502. It must be evident, that whatever objections exist to assuming the existence of iodohydrates of organic bases, apply with equal force to the existence of chlorohydrates, bromohydrates, fluohydrates, &c. &c.

5503. Agreeably to the representations of Berzelius, founded, in great measure, on the investigations of Bouchardat, the vegetable alkalies have, in common with ammonia, a propensity to combine with two atoms of iodine, the recognised combinations consisting, not of an atom of iodine and an atom of the vegetable alkali, but of a compound of iodine and an iodohydrate of such an alkali. This view of the subject is alleged to be corroborated by the fact, that the combinations, with organic bases alluded to, are obtained, with pre-eminent facility, by a double decomposition consequent to the reaction of bi-iodide of potassium with a salt formed by an acid with one of these alkalies. The precipitates of the alkalies in question, thus obtained, are nearly insoluble, and in many instances well characterized. Hence the bi-iodide of potassium may be more confidently relied upon as a precipitant of the organic bases than tannic acid. From the precipitated

\* This does not altogether confirm the allegation quoted from O. Henry (5307, see), that tannic acid may be used as a general mean of precipitating, and thus obtaining the vegetable alkalies. No suggestion is made as to any advantageous method of extracting the alkali from the precipitate.

compound of iodine with the organic base, the latter may be liberated by subjecting them in water to sulphydric acid. By these means the iodine is converted into iodohydric acid, after which, an inorganic alkaline base will separate the organic alkali in an isolated state. Berzelius' Report for 1840, p. 179.

5504. It may be proper to mention, that bi-iodide of potassium is formed by digesting iodine in a solution of iodide of potassium, usually erroneously designated in the shops as hydriodate of potash. The bi-iodide can only exist in solution, according to Berzelius.\*

### *Constitution of the Organic Alkalies.*

5505. All the organic alkalies are constituted of hydrogen, carbon, oxygen, and nitrogen, except *melamine*, *nicotina*, and *anilina*, which are devoid of oxygen.

5506. It is remarkable that these alkalies contain a very large proportion of carbon, and that in all of them nitro-

\* "*Chloride of Gold as a test of certain Vegetable Alkalies.*—MM. Larocque and Thibierge find, that perchloride of gold is a more decisive test of certain vegetable alkalies, than the double chloride of sodium and gold already employed for this purpose. The following are the colours of the precipitates which it produces with the salts of the annexed alkalies dissolved in water:—Quinia, buff-coloured; cinchona, sulphur-yellow; strychnia, canary-yellow; veratria, slightly greenish-yellow; brucia, milk, coffee, and then chocolate-brown; morphia, yellow, then bluish, and lastly violet. In this last state the gold being reduced, the precipitate is insoluble in water, alcohol, the caustic alkalies, and sulphuric, nitric, or hydrochloric acids; but forms with aqua regia a solution which is precipitated by protosulphate of iron.

"All these precipitates, with the exception mentioned, are very soluble in alcohol, insoluble in ether, and slightly soluble in water. They appear to be combinations of gold, chlorine, and the vegetable alkali, since their alcoholic solutions, treated with tannin, give a greenish-blue precipitate of reduced gold; if the solution be filtered, and the alcohol be evaporated by heat, a precipitate of tannate of the alkali employed is formed. The liquor again filtered, gives with nitrate of silver a white precipitate insoluble in nitric acid, but soluble in ammonia.

"Among the reactions of chloride of gold, those which occur with morphia and brucia, to the authors appear to be especially important, as they are sufficiently marked to prevent these alkalies from being mistaken for each other, and also yield pretty good characteristics for distinguishing brucia from strychnia.

"The authors have also, as the results of their experiments, arrived at the following conclusions:—

"1st. By the aid of reagents it is possible to determine the presence of morphia, strychnia, and brucia, in substances, which, after being mixed with the salts of these alkalies, have undergone the vinous, acetic, or putrefactive fermentation. M. Orfila has already shown that the putrefactive fermentation does not alter morphia.

"2dly. Crystallized iodic acid, or a concentrated solution of this acid, is susceptible of being decomposed by neutral azotized bodies; but a dilute solution of the acid cannot be decomposed by them, unless there be added concentrated sulphuric acid, crystallizable acetic acid, oxalic, citric, or tartaric acid.

"3dly. Iodic acid should not be employed as a test of morphia without the greatest caution.

"4thly. Perchloride of gold produces such effects with the vegetable alkalies, as serve to distinguish morphia, brucia, and strychnia, from each other.

"5thly. The reagents, on which the greatest reliance may be placed as tests of morphia, are nitric acid, neutral perchloride of iron, and perchloride of gold.

"6thly. By the use of reagents, morphia, which has been mixed with beer, soup, or milk, may be detected.

"7thly. It is also easy to prove, by reagents, the presence of meconic acid in soup or milk, especially when the meconate of lead is decomposed by dilute sulphuric acid." *Journal de Chimie Médicale*, Octobre, 1842 (5265).



gen is likewise a constituent. It was at one time alleged, that agreeably to the analysis of Liebig, in an equivalent of any of the alkalies of this class, only one atom of nitrogen could be found; but subsequent observation has shown that this rule has exceptions, since strychnia and brucia are found each to contain two atoms of the element in question; and in some other organic bases, the proportion of nitrogen exceeds that of an atom to each equivalent.

5507. As morphia differs from codeia only in having one atom more of oxygen; and as the three alkalies of Peruvian bark differ only in the same way; quinia having one atom of oxygen more than cinchonia, and aricina one atom more than quinia, the idea has been suggested, that in either case a compound radical may exist, capable of different degrees of oxidation: hence morphia might be a bioxide, and codeia a protoxide, of the same radical; and in like manner cinchonia might be a protoxide, quinia a bioxide, and aricina a trioxide, of one radical. But were such the case when presented to chlorohydric acid, these oxides should severally have their basic oxygen replaced by as many atoms of chlorine, which is alleged not to arrive when the experiment is tried. They all form muriates, so called, under the circumstances alluded to, or chlorohydrurets, agreeably to the view which I have taken respecting their composition (5436). See Kanc, 1078.

#### OF IMPORTANT NEUTRAL ORGANIC PRINCIPLES.

*Of Salicin, a neutral Principle, and of some Compounds derived from it, or to the production of which it contributes.*

5508. The discovery of an analogy, if not an identity, between the properties of the oil of gaultheria, and that of *spirea ulmaria*, induces the idea that there may be essential oils in other vegetables of the United States, which may be worthy of examination. Under these circumstances, every fact connected with the origin of the oil of *spirea ulmaria*, must be interesting to the lover of science. I have, therefore, deemed it expedient to give some details respecting salicin, the principle from which the artificial "hydruret of salicyl," saliculous acid, is extricated, and likewise of some substances resulting from the reaction of salicine with other bodies (5321, &c.).

5509. *Salicin*,  $C^{12} H^{22} O^{16} + 6HO$ . This interesting principle, discovered by Le Roux and Buckner, is found in the bark and leaves of *bitter* willows, and in that of some species of poplar. It is obtained by subjecting the bark, in a divided state, to successive portions of boiling water. The resulting decoctions being united and concentrated by further ebullition, are, while boiling, mingled with litharge gradually added until the liquor becomes colourless. The lead, combining with the salicin, may be precipitated from it, together with various impurities, by adding sulphuric acid at first, and then sulphide of barium. With the aid of charcoal, and repeated crystallization, the salicin is obtained finally in delicate, silky white transparent needles, permanent in the air. It is bitter and inodorous, but without any reaction with vegetable colours. It sustains no loss of weight at a boiling heat, but at a higher temperature is decomposed, becoming yellow, resinous, evolving inflammable vapour, and finally leaving a carbonaceous residue. It is soluble in five parts of cool water, and in any proportion in boiling water. It is no less soluble in alcohol, but is insoluble in ether, or the fixed oils. It forms with concentrated sulphuric acid a blood-red solution, which is blackened when heated. Any bark which contains salicin is liable to be reddened by contact with sulphuric acid. Salicin is thrown down from any of its solutions by acetate of ammonia. That saliculous acid is evolved by distilling salicin with sulphuric acid and bichromate of potash, has already been mentioned (3066, 5320).

5510. *Saliretine*,  $C^{30} H^{15} O^7 + HO$ , is a resinous substance produced by boiling salicin either in diluted sulphuric, or chlorohydric, acid. It is soluble in caustic alkalies, excepting ammonia; likewise in alcohol or ether, but is insoluble in water. By sulphuric acid it is changed to a blood-red; and it seems likely that it is to the generation of this resin that the reddening of salicin by that acid is due. One atom of hydrated saliretine, with an atom of raisin sugar, comprise the elements of one atom of hydrated salicin.

5511. *Chlorosalicine*,  $C^{42} H^{25} Cl^4 O^{22}$ . When a solution of salicine is impregnated with chlorine, a crystalline deposition ensues, which dissolves in water with difficulty, but in hot alcohol with ease. It may be considered as comprising the same elements as salicin, excepting the substitution of four atoms of chlorine for a like number of hydrogen.

5512. When during the impregnation, in the process above described, the temperature is raised to  $140^{\circ}$ , a compound is obtained in which seven atoms of hydrogen have been replaced by a like number of chlorine; formula  $C^{48} H^{18} Cl^7 O^{18}$ .

**5513. Rutiline.** Under this appellation Braconnot designates a substance arising from the decomposition of salicine by concentrated sulphuric acid. Pure rutiline, when moist, appears at first reddish-brown, but soon becomes yellow; when desiccated, its colour is brownish-black. It is friable, insipid, inodorous, and insoluble in water or alcohol. By inorganic acids its hue is changed to a beautiful red, by alkalies to a deep violet.

**5514. Phloridzine**,  $C^{48}H^{52}O^{12} + 6HO$ . The preceding name has been given to a principle discovered by De Koninck in the bark of the roots of apple, pear, cherry, and plum trees. In composition and properties it is very analogous to salicin; and differs, as respects elementary constituents, only in having two more atoms of oxygen. Phloridzine is extracted from any bark in which it may exist, by boiling alcohol of the specific gravity of 850. From the alcoholic solution thus obtained, it crystallizes on the removal of the solvent in delicate, colourless, silky, rectangular, prismatic needles; which are soluble in 1000 parts of cold water, and in every proportion in boiling water. The solution has an astringent, bitter savour, without any power to change vegetable colours. In alcohol it is also soluble, but is insoluble in ether. At  $212^{\circ}$  it loses four atoms of water of crystallization. It melts at  $320^{\circ}$ , but is not decomposed under  $390^{\circ}$ .

**5515. Phloridzeine**,  $C^{44}H^{50}O^{10}N^2$ . This name is employed to designate a substance obtained by the reaction of phloridzine with ammonia and atmospheric oxygen. As its name differs from that of this last mentioned substance only in the presence of an additional e, and conveys no idea of its composition, it seems very ill chosen. By simultaneous contact with atmospheric oxygen and gaseous ammonia, moist phloridzine is transformed into a red matter, which, readily dissolving in liquid ammonia, may be precipitated therefrom by acids. The precipitate, thus obtained, is phloridzeine. It is formed by the addition of eight atoms of oxygen, and the elements of two atoms of ammonia, to phloridzine. An ammoniacal solution of phloridzeine, evaporated within an exhausted receiver, including some fragments of the hydrate of potassa, is converted into a purple blue residuum, having a cupreous metallic brilliancy. This residuum is unalterable in dry air, soluble in cold water, to which it communicates a magnificent purple blue. This solution is decolorized by deoxidizing substances, but resumes the oxygen thus lost, and the blue colour, on being re-exposed to the air. This blue residuum is compounded of an atom of phloridzeine, and an atom of ammonia.

**5516. Asparagine, asparamide, altheine, agedoile.**—These are the synonymous appellations of a principle capable of forming a crystalline hydrate,  $C^{10}H^{16}O^8N^2 + 2HO$ , which loses its water of crystallization at  $248^{\circ}$ . It is found in asparagus, in liquorice, in the root of althea officinalis, in that of the potato, and various other plants. It crystallizes in large, transparent, light rhombic prisms. It has a cooling and somewhat nauseous taste, is soluble in water and diluted alcohol, but insoluble in this last mentioned liquid when concentrated, or in ether. By reaction with acids or alkalies, assisted by heat, asparagine is resolved into ammonia, and an acid called *spartic*. The considerations which were mentioned as giving importance to caffeine, must apply to asparagine as being a highly nitrogenated principle, since such principles, without any very sensible activity, may, agreeably to the suggestions of Liebig, be of importance in supplying the nitrogen requisite to facilitate the functions of life.

**5517. Tarazacine.**—Mons. Polex has extracted from the milky juice of the leontodon taraxacum, a crystallizable substance, which he has named

taraxacine. The milky juice of the plant is boiled in distilled water, by which means the albumen is coagulated, involving the resin, fatty matter, and caoutchouc. The concentrated liquor is filtered, and allowed to evaporate spontaneously in a place moderately warm. The taraxacine crystallizes during this operation, and may be afterwards purified by repeated crystallizations from alcohol or water. It forms arborescent or star-shaped crystals. These melt readily, are not volatile, and have a bitter and rather acid taste. They are sparingly soluble in cold water, but dissolve abundantly in boiling water, in alcohol, or ether. They dissolve in the concentrated acids without being decomposed. Taraxacine contains no oxygen.

5518. When the albuminous precipitate, which has been separated from the water, is boiled in alcohol, a colourless substance, in the form of small cauliflower crystals, is obtained on the evaporation of the alcohol. On being dried it falls into a powder, very fusible, but difficult to be ignited. It is insoluble in water, but very soluble in alcohol and ether. The solution has an acid taste, and yields no precipitate with acetate of lead. It is insoluble in the caustic alkalies. Berzelius' Report on the Progress of Science.

#### *Of certain Vegetable Principles devoid of Nitrogen.*

5519. I have quoted verbatim, from Gregory and Liebig's new edition of Turner's Chemistry, 1118, the following account of vegetable principles described as *devoid of nitrogen, and of a nature not yet fully ascertained*: in hopes that some of my pupils may be induced, by their investigations, to endeavour to remedy the imperfection in chemical science thus admitted to exist.

5520. "*Gentianine*.—Extracted by ether from the root of *Gentiana lutea*, and purified by solution in alcohol. It forms golden yellow crystals of a very bitter taste, which may be sublimed. According to Trommsdorff, when quite pure it is no longer bitter, and has acid properties, expelling carbonic acid from the alkaline carbonates, and forming, with the alkalies, golden-yellow crystallizable salts.

5521. "*Santonine* is found in the flowers of several species of *Artemisia*, and in the so called *Semen Cynæ*, which is much used as a vermifuge, and is a mixture of the flowers, buds, and unripe seeds of these plants. Four parts of this mixture are digested with one-half of slaked lime and twenty of alcohol, at 90 per cent. The santonine is dissolved in combination with lime and with a brown resin. It is separated by acetic acid, but is still contaminated with resin. This is removed by washing with a little alcohol; and the residue being dissolved in eight or ten parts of alcohol at eighty per cent., and boiled with animal charcoal, the liquid, on cooling, deposits santonine in colourless crystals, which must be kept in the dark, as they become yellow when exposed to light. It is tasteless and odourless, fusible and volatilizable, sparingly soluble in water, more easily in alcohol and ether. It has acid properties, and forms salts with potash and soda, the latter of which crystallizes. Acids dissolve it without altering it, and water precipitates from the solution the santonine unchanged. It forms crystalline salts with lime and baryta, and insoluble compounds with many metallic oxides. Its composition is represented by the formula  $C^8 H^{10} O$  (Ettling); but its atomic weight must be twelve times greater, to judge from its capacity of saturation.

22. "*Picrolichenine*.—Discovered by Alms in the lichen *Variolaria* *va*, from which it is extracted by alcohol. It is purified from a green matter which accompanies it, by washing with a dilute solution of carbonate of soda. It forms obtuse double four-sided pyramids, which have a most acrid bitter taste. When acted on by ammonia in a close vessel, it dissolves; and after some time the solution becomes yellow, and deposits yellow crystals, which are not bitter. When the ammoniacal solution is exposed to the air, a dark red substance is formed, which indicates an analogy between this substance and oricine, which, as will be hereafter mentioned, occurs in other lichens. Its composition is unknown, but it contains no nitrogen. It is said to be powerfully febrifuge.

23. "*Cetrarine* is analogous to the preceding. It occurs in several mosses, as in Iceland moss, *Cetraria Islandica*, and in *Sticta pulmonacea*. It is extracted by alcohol. It forms a fine white powder, very bitter to the taste. Concentrated hydrochloric acid colours it deep blue. Its other properties are little known, but it is said to be used as a febrifuge in Italy.

24. "*Elaterine* is the active principle of elaterium, the inspissated juice of the fruit of *Momordica elaterium*. The elaterium is dissolved in alcohol, and the concentrated solution thrown into water, which precipitates the elaterine. By repeating this process it is obtained pure. (Morris.) It forms delicate silky crystals of a very bitter taste. One-sixteenth of a grain acts as a drastic purgative. Its composition is unknown. It merits a more minute examination.

25. "*Colocynthine*.—The bitter and purgative principle of colocynth, is the pulp surrounding the seeds of *Cucumis colocynthis*. It is obtained by evaporating the infusion made with cold water, at first in oil of sweet almond, which afterwards solidify into a brown, brittle mass. It is soluble in water, alcohol and ether, intensely bitter, and acts as a drastic purgative. Its chemical characters are imperfectly known, and it is probably a mixture.

26. "*Byronine*.—Obtained by a somewhat similar process from the juice of the root of *Byronia alba* and *B. dioica*. It forms a brown or yellowish-white mass, having a taste at first sweetish, then acrid and very bituminous. It is soluble in water and alcohol, insoluble in ether. It appears to contain several principles, and is probably a mixture of several compounds. It is a drastic purgative, and has poisonous properties.

27. "*Mudarine* is found in the bark of the root of *Calotropis Mukorin* (Duncan.) It is soluble in water and alcohol. The aqueous solution gelatinises when heated to 95°; at a higher temperature it is coagulated, the mudarine separating as a viscid mass. On cooling, it is slowly and completely redissolved. Mudarine has powerful emetic properties.

28. "*Scillitine*.—Obtained from the juice of squills, the bulb of *Scilla maritima*. A brittle mass, of a nauseous bitter taste. It acts as an emetic and a purgative, and appears to be poisonous. (Tilloy.)

29. "*Cathartine*.—Similar to the preceding. Obtained from the leaves of *Senna* and *C. lanceolata*, and from some other plants. It has a bitter and nauseous taste, and purgative properties.

30. "*Xanthopictine* is found in the bark of *Xanthoxylum Clava Herodoti*. It forms greenish-yellow silky crystals, intensely bitter and astringent. It is very soluble in alcohol, and has neither an acid nor an alkaline reaction. Its action on the system has not been studied, but the bark is used as a remedy in the Antilles.

5531. "*Columbine*.—Obtained from columbo, the root of *Menispermum palmatum*. It is extracted by alcohol or ether. Forms colourless and transparent oblique rhombic prisms, or delicate white needles: is neutral, fusible, and contains no nitrogen. It is very bitter, and becomes still more so when dissolved in acetic acid. It is the active principle of columbo. (Wittstock.)

5532. "*Quassine* is the bitter principle of the wood of *Quassia amara*. When pure, it forms small white opaque prisms, which are intensely bitter, and very soluble in alcohol. From the analysis of Wiggers, its formula is probably  $C^{20}H^{12}O^6$ .

5533. "*Lupuline* is the bitter principle of hops, the female flower of *Humulus lupulus*. It is neutral, uncrystallizable, soluble in water and alcohol, and very bitter.

5534. "*Lactucine* is the active principle of *Lactucarium*, the inspissated juice of *Lactuca sativa*, *L. virosa*, and *L. scariola*. It forms yellowish indistinct crystals, which have a strong persistent, bitter taste. It is sparingly soluble in water, very soluble in alcohol. The anodyne effects of lactucarium are most probably to be ascribed to lactucine.

5535. "*Ergotine*.—Discovered by Wiggers in the ergot of rye, *Sclerocornutum*. It is obtained as a brown powder, of a pungent and bitter taste, and is conceived by Wiggers to be the active principle. He describes it as narcotic and poisonous; but its composition and properties are unknown, and it is most probably a mixture.

5536. "*Porphyroxine*.—Discovered by Merck in Bengal opium. It forms small brilliant crystals, which, when dissolved in diluted mineral acids and heated, yield a red colour. It is neutral, soluble in alcohol and ether, insoluble in water. It is quite distinct from the other crystalline substances found in opium, but as yet has been but little examined.

5537. "*Saponine* is found in the root of *Saponaria officinalis* and *Gypsophila Struthium*. It is extracted by alcohol, and purified by repeated crystallization from that solvent. It forms a white brittle mass, not crystallizable. It has a taste at first sweetish, then acrid and irritating; and the smallest quantity of the powder introduced into the nostril causes violent sneezing. It is soluble in water; and the solution, even when very dilute, froths like a solution of soap. The root is used as a detergent.

5538. "*Smilacine*: Syn. *Parilline*, *Salseparine*.—Extracted by alcohol from *Sarsaparilla* (*Smilax sarsaparilla*). It is crystallizable, soluble in hot water and alcohol, colourless and tasteless. Its solutions have the property of frothing. Its formula appears to be  $C^{15}H^{12}O^3$ . (Poggiale; Thubœuf; Petersen.) The Chinova bitter of Winkler, found in *Chinova*, has been shown by Buchner, jun., to be identical in its properties with smilacine; and Petersen has shown that its formula is  $C^{15}H^{12}O^3$ , differing from that of smilacine only by 1 eq. of water.

5539. "*Senegine*: Syn. *Polygaline*, *Polygalic Acid*.—Is found in *Polygala senega* and *P. virginica*. It is a white powder, at first tasteless, afterwards very acrid, and causing a feeling of astringency in the gullet. It also acts as a sternutatory. According to Quevenne, its formula is  $C^{11}H^{18}O^{11}$ .

5540. "*Guaiaicine*.—Discovered by Trommsdorff in the wood and bark of *Guaiaecum officinale*. It forms a yellow brittle mass, which has a sharp acrid taste. It is no doubt one of the active principles of the gum-resin of guaiacum, and is the cause of its acrid taste.

5541. "*Plumbagine* occurs in the root of *Plumbago Europea*. It is

tracted by ether, and forms fine orange-yellow crystals, which at first ve a sweet taste, followed by a burning acrid sensation. It is neutral, d soluble in hot water. Alkalies give to its solution a cherry-red colour, t acids restore the yellow. The root also contains a peculiar fat, not yet vestigated, which gives to the skin a lead-gray colour, whence the name the plant is derived.

5542. "*Cyclamine*: Syn. *Arthanitine*.—Found in the root of *Cycla- n Europæum*. It crystallizes in fine white needles, of a burning acrid te, and having emetic and purgative properties.

5543. "*Peucedanine*.—Discovered by Schlatter in the root of *Peucedam officinale*. Extracted by alcohol. It forms delicate white prisms, fuble, insoluble in water, soluble in alcohol and ether. The solution has acrid burning taste. It is neutral. Formula,  $C^4 H^8 O$ . In some roots at had long been kept, Erdmann found a modification of peucedanine, dif- ing from it only in being insoluble in ether. Its formula was  $C^8 H^8 O^8$ ; ick only contains one atom of oxygen more than the formula of peuce- nine doubled, and was, therefore, probably formed from it by the action the atmosphere.

5544. "*Imperatorine*.—Found by Osann in the root of *Imperatoria Os- utium*. Is extracted by ether. It forms long transparent prisms, has an rid burning taste, is neutral, fusible, insoluble in water, soluble in alcohol d ether. Formula,  $C^{24} H^{12} O^5$ . (F. Dœbereiner.)

5545. "*Tanghinine*.—Extracted by ether from the seeds of *Tanghinia adagascariensis* after the fixed oil has been removed by pressure. It is ystallizable; soluble in water, alcohol, and ether; very bitter and acrid. is also poisonous. (Henry and Ollivier.)

5546. "*Meconine*.—Discovered by Couerbe in opium. It is dissolved, ong with most of the other ingredients of opium, when water is used as a solvent; and, being soluble in water, it remains dissolved when mor- ia, narcotine, &c., are precipitated by ammonia. Part of it, however, ls along with the precipitate. It is purified by the alternate action of al- hol, water, and ether; in all of which it is soluble with the aid of heat. hen pure, it forms fine white prisms, which are at first tasteless, after- urds acrid. It is fusible, and may be sublimed unchanged. It requires : solution 266 parts of cold water, and 18 parts of boiling water. When ated with water, it first melts into an oily fluid, and gradually dissolves. lphuric acid, diluted with half its weight of water, dissolves meconine, rming a colourless solution, which, when heated, becomes dark green. ater throws down from the green solution brown flocks, which dissolve alcohol with a rose-red colour. From this alcoholic solution the salts of rmina, lead, and tin, throw down fine red lakes. Meconine is quite neu- d. Its formula, according to Couerbe, is  $C^{10} H^8 O^4$ , or rather the half of s; but its composition cannot be considered as ascertained. By the ac- a of chlorine it is converted into mechloic acid, and nitric acid changes it to nitro-meconic acid.

5547. "*Cubebine*.—Found by Soubeiran and Capitaine in cubeb pep- r (the seeds of *Piper Cubeba*). It is neutral, crystallizable, tasteless, aringly soluble in water and alcohol. Its formula is probably  $C^{24} H^{12} O^{12}$ .

5548. "The following substances are neutral, have generally a bitter te or are tasteless, and are to a certain extent problematical, as the ob- rvations regarding them are very imperfect. It is probable that many of em will be found identical with some of the preceding.

- "Alcornine, from Alcornico, the root of *Hedwigia virgelioides*.
- "Alismine, from *Alisma Plantago*.
- "Arnicine, from *Arnica montana*.
- "Asclepine, from the root of *Asclepias gigantea*.
- "Absinthiine, from the flowers of wormwood, *Artemisia absinthium*.
- "Antiarine, from *Antiaris toxicaria*.
- "Amanitine, from *Agaricus muscarius*, *A. bulbosus*, and others.
- "Buenine, from the bark of *Buena hexandra*.
- "Canelline, from the bark of *Canella alba*.
- "Cascarilline, from the bark of *Croton Eleutheria*.
- "Cassiine, from *Cassia fistula*.
- "Centaurine, from *Erythræa Centaurium*.
- "Colletine, from *Colletia spinosa*.
- "Coriarine, from *Coriaria myrtifolia*.
- "Cornine, from the bark of the root of *Cornus florida*.
- "Corticine, from the bark of *Populus tremula*.
- "Cytisine, from the seeds of *Cytisus Laburnum*.
- "Daphnine, from the bark of *Daphne Mezereum* and other species  
is crystallizable.
- "Datiscine, from *Datisca cannabina*.
- "Diosmine, from the leaves of *Diosma crenata*.
- "Euonymine, from the seeds of *Euonymus Europæus*.
- "Fagine, from *Fagus sylvatica*.
- "Frazinine, from the bark of *Fraxinus excelsior*.
- "Geraniine, from the *Geraniaceæ*.
- "Granatine, from unripe Pomegranates.
- "Guacine, from Guaco leaves.
- "Hesperidine, from the spongy part of the Orange rind. Crystalliz
- "Hyssopine, from *Hyssopus officinalis*.
- "Ilicine, from *Ilex aquifolium*. Crystallizable.
- "Lapathine, from *Rumex obtusifolius*.
- "Ligustrine, from the bark of *Ligustrum vulgare*.
- "Lilacine, from *Syringa* or Lilac.
- "Liriodendrine, from the bark of the root of *Liriodendron tulipifera*.
- "Menyanthine, from *Menyanthes trifoliata*.
- "Melampyrine, from *Melampyrum nemorosum*.
- "Narcitine, from *Narcissus pseudo-narcissus*.
- "Olivile, from *Olea Europæa*.
- "Olivine, from the leaves of *Olea Europæa*.
- "Primuline, from the root of *Primula veris*.
- "Pyrethrine, from the root of *Anthemis Pyrethrum*.
- "Populine, from the bark and leaves of *Populus tremula*.
- "Phillyrine, from the bark of *Phillyrea media and latifolia*.
- "Rhamnine, from *Rhamnus frangula*.
- "Scordine, from *Teucrium Scordium*.
- "Scutellarine, from *Scutellaria lateriflora*.
- "Serpentarine, from *Aristolochia serpentaria*.
- "Spartiine, from *Spartium monospermum*.
- "Spigeline, from the root and leaves of *Spigelia anthelmia*.
- "Tanacetine, from *Tanacetum vulgare*.
- "Tremelline, from *Tremella mesenterica*.
- "Zedoarine, from the root of *Curcuma aromatica*."



## ETHERS, AND THEIR COMPOUNDS AND DERIVATIVES.

*Of Ethyl Ethers (3090).*

549. Agreeably to the classification proposed in treatise of ethyl (3077), common ether, the oxide of that compound radical, as the first in the class of simple ethyls, is primarily to be the object of attention.

*the Oxide of Ethyl, common Ether, erroneously called Sulphuric Ether,  $C^4 H^5 O$ .*

550. It has been mentioned, that this compound is now called ether, on account of a sort of prescriptive claim, although the name by which it is designated has been appropriated to a class of bodies having, in common with it, the important characteristics (3083).

551. *Of the Properties of the Oxide of Ethyl.*—The oxide of ethyl is a colourless, transparent, volatile liquid, having only seven-tenths of the density of water, or seven-tenths of that of absolute alcohol.

552. It is so inflammable, that a jet of it may be ignited throughout its whole length, when extending many feet. It has a fragrant smell and an aromatic taste, which, though pungent and stimulating, is not unpleasant. Its density to that of water at  $60^\circ$ , is as 725 to 1000. It boils between  $97^\circ$  and  $98^\circ$ , and congeals before it reaches the temperature of  $-47^\circ$ . With alcohol it unites in all proportions, but may be recovered therefrom by agitation with twice its bulk of water, which, combining with the alcohol, subsides gradually, allowing the liberated ether to rise as a superstratum easily separable.

553. One part of ether dissolves in ten of water, and one part of this liquid in thirty-six of ether. Essential oils are soluble in ether to any extent, and also the margaric and oleic oils of fixed oils; but stearine is so little soluble in ether, that it is employed to deplete it of the two other oils mentioned constituents of fat. Ether is likewise a solvent of most of the resins. It takes gold, in the metallic state, from a solution of the chloride of that metal, forming an ethereal solution, which has been employed to gild steel. It dissolves several of the haloid compounds, especially the chloride of zinc and bichloride of mercury;

also several organic acids, the acetic, gallic, benzoic, oleic, and stearic, for instance. The solubility of various organic alkalies in ether has been mentioned in treating of their extraction. Of sulphur, it takes up  $\frac{1}{10}$  of its weight; of phosphorus, from  $\frac{1}{17}$  to  $\frac{1}{15}$ , according as it is more or less free from water. Bromine and iodine are copiously soluble in ether, the solutions being, however, liable to spontaneous decomposition, producing bromohydric and iodo-hydric acid, and some other products which have not been studied.

5554. According to Liebig, gaseous chlorine decomposes ether immediately, each bubble inflaming spontaneously at the ordinary temperature of the air, giving birth to chlorohydric acid, and liberating carbonic acid. *Anhydrous sulphuric acid, in the cold*, generates from ether, isethionic, and ethionic acid, besides *heavy* oil of wine, light oil of wine (5537), and sulphovinic acid. At a high temperature, these acids are resolved into heavy oil of wine, water, ether, sulphurous acid, and olefiant gas.

5555. *Nitric acid*, aided by heat, converts ether into formic, oxalic, and carbonic acid, together with aldehyde.

5556. *Of chlorohydric acid gas*, ether absorbs a large quantity; and by distilling a concentrated solution, chloride of ethyl is generated.

5557. *Dry alkaline hydrates* have no reaction with pure ether at ordinary temperatures, but when moisture and oxygen are present and heat is employed, cause it to become brown after some time, and to form alkaline acetates or formiates. Potassium and sodium are alleged, by Liebig, slowly to deoxidize ether, and finally to decompose it into gaseous and oily carbon-hydrogens, forming oxides with which the ether combines as an acid.

5558. *In presence of iron, lead, or zinc*, with access of oxygen, this element is absorbed, generating acetates.

5559. *Ammoniated ether* may be obtained by subjecting ether, shaled lime, and chloride of ammonium, to the distillatory process.

5560. *An ethereal solution of the bi-iodide of mercury* is obtained by the solution of one part of the bi-iodide in twelve parts of ether. One part of the *bichloride* of iron dissolves in four parts of ether. On agitating an aqueous solution of this bichloride with ether, this liquid takes the bichloride from the water, forming a golden-yellow liquor, from which light causes a crystalline protochloride to precipitate.

5561. In consequence of the solubility of narcotina, and insolubility of morphia in ether, it is employed to denarcotize opium in preparing a for making denarcotized laudanum.

5562. The tension of the vapour of ether being, per se, adequate to support a pressure about half as great as that of the atmosphere, it consequently doubles the volume of any gas to which it may be added. This may be made evident by introducing a measured quantity of any gas into a volumescopé, and adding, subsequently, a portion of ether\* (818).

\* Agreeably to the experiments of Dalton, the vapour of any liquid in contact with the air, or any permanent gas, supports a proportion of the atmospheric pressure, which bears the same ratio to the whole pressure, as the height of the column of mercury, which the vapour in question will support, per se, in an exhausted receiver, &c.

**5563.** It was mentioned, in treating of olefiant gas, that when a volume of that gas was mingled with four volumes of hydrogen and two of oxygen, no condensation ensued when the mixture was ignited. The elements of the gas combining with those of water in the act of uniting, generated a new gas containing the elements of both. It was likewise mentioned, that half a volume of ether had about as much efficacy when substituted for the olefiant gas, as a whole volume of the latter.

**5564.** This is interesting, as tending to show that in the same space ether vapour contains about twice as much carbon and hydrogen as olefiant gas (1276).

**5565.** *Of the Means of obtaining Ether.*—Respecting the means by which ether is elaborated, a general explanation has already been given in treating of ethyl (3804). The old recipe for its manufacture, was to distil two measures of officinal alcohol of about 0.840 with one of sulphuric acid, without any subsequent addition of alcohol; but, latterly, the proportions have been nearly reversed by using, at the outset, nine parts of acid, by weight, with five parts of alcohol, the proportion of this liquid being sustained by subsequent additions, compensating the diminution resulting from the vaporization of the products. Liebig recommends, that in using these proportions, the alcohol be added to the acid in a copper or cast iron vessel, the liquids being mingled by stirring them with an iron spatula; but agreeably to the experience of a manufacturer in this vicinity, who, for many years, was in the practice of distilling a large quantity of the etherifying materials at a time, it is preferable to introduce the alcohol into the alembic first, and then the acid, in a continued stream. This stream, by its superior weight, produces a descending current, carrying along with it the alcohol with which it comes into contact, and forming a compound, of which the boiling point is about  $280^{\circ}$ . The descending current displacing the liquid previously near the bottom of the alembic, causes it to ascend at the sides, and thus establishes a circulation, by which a complete intermixture of the materials is effected. The heat generated meanwhile, acting upon some of the alcohol not in contact with the acid, is, in a greater or less degree, expended in vaporizing a portion of this ingredient, which, condensing in the receiver, should be restored to the body of the still or retort employed. This method of manipulation, to which I have myself long resorted, has several advantages over that of Liebig; agreeably to which, the alcohol being poured over the acid, and in contact with the air, must sustain some loss by vaporation. The mixture being made in one vessel, and the distillation in another, causes unnecessary trouble, and the heat generated by combination is lost, which, in the other case, requires little aid from the fire employed to cause the distillation to commence.

**5566.** The most advantageous method of applying heat in this and many other cases, is that already described of a furnace having coals in a drawer which can be withdrawn in an instant, partially or wholly, so as to render the temperature perfectly controllable (963). Where carburetted hydrogen

the height of the mercury in the barometer at the same time. Hence, as the column which the vapour of ether will support, per se, at ordinary temperatures, is about half that of the usual height of the barometric column, it follows, that when liquid ether is introduced into any gas, its vapour relieves the gas of half the pressure, and at the same time deprives it of half the space, so that they require twice as much room as the gas required, per se; consequently the volume of the mixture becomes twice as great as that of the gas previously.

is supplied to a laboratory, from a gas light establishment, and a glass retort is to be used, a tube, forming a circle of four or five inches diameter, and perforated at intervals of about half an inch, so as to allow in its circumference from twelve to twenty gas lights, forms an efficient mean of applying a competent and manageable heat. If the distillation of the etherifying materials be carried on until the resulting carbonaceous mass swells up so as to endanger its coming over, it will be found that the first products consist of ether with undecomposed alcohol, then ether and water, and afterwards ether with sulphurous acid and heavy oil of wine, forming a yellow liquid. But, according to Liebig, if before alcohol ceases to come over in a minute proportion, absolute alcohol be gradually added by a tube, with a very small aperture at the lower end, terminating under the surface of the mixture so as to keep it at the same level, by compensating the diminution resulting from the distillation, the evolution of ether and water continues without the extrication of sulphurous acid and oil of wine. If, says Liebig, "the operation be well managed, only ether and water will be evolved; and the acid may serve for the preparation of ether, indefinitely, without perceptible diminution." When alcohol of the official density is used, in the way thus proposed, the acid soon becomes too much diluted to perform the office of an etherifier. Liebig admits that when the spirit of wine employed, contains 90 per cent. of anhydrous alcohol, only 31 parts can be etherified by 90 of sulphuric acid, and when the proportion of water to the acid exceeds the ratio of 9 to 2, ether cannot be evolved.\*

5567. As respects the refrigeration of the ether vapour, as it comes over, I have been accustomed to employ an inverted open-necked bell-glass, through the axis of which a glass tube passes, being made to form an air-tight juncture with the neck, by means of a gum elastic bag, cut off near the bottom, so as to embrace the neck of the bell, while its own neck embraces the tube, being secured to both by ligatures. The beak of the retort is drawn out by means of a fire, and bent at right angles so as to descend into the upper orifice of the refrigerating tube. The bell is supplied with ice and water, this liquid being drawn off by a syphon as the ice melts, in order to allow more to be added. The refrigerating tube must terminate within a thin bottle, surrounded by ice and water. It is usually recommended to separate the ethereal portion of the product, and rectify it over milk of lime, or a

\* That sulphovinic acid is the inevitable consequence of mixing and heating sulphuric acid with alcohol beyond a certain point, has already been mentioned in treating of ethyl (3036) and of sulphovinic acid (5217). This combination arises probably from the affinity of hydrous sulphuric acid, sulphate of water, when undiluted, for etherine, and for more water, so that while one portion attracts the ether of the alcohol, the other attracts the water.

Agreeably to the representations of Liebig, above stated, if, during the etherification of alcohol by sulphuric acid, that ingredient be supplied in the proportion necessary to compensate the evolution of ether and water, a given quantity of acid may serve to etherify alcohol to an unlimited extent. The fact that, under such circumstances, only the alcohol appeared to undergo decomposition, being noticed by Michaelis, led him to infer that the part performed by the acid was merely catalytic. But this inference is irreconcilable with the well-established fact of the formation of sulphovinic acid whenever alcohol and sulphuric acid are mingled in due proportion and heated (5298). Yet, upon this view of the phenomena it is difficult to understand how the mixture can at the same time evolve ether from one portion of the sulphovinic acid present, and yet absorb alcohol to form another portion of the same acid. The most feasible explanation is, that the contact of the alcohol with the acid, in one part of the mixture, causes a reduction of temperature to the point at which the acid can combine with oxide of ethyl, while in other parts of the mixture, the temperature may be sufficiently high to cause other atoms of the same base to be disunited from the acid.

caustic alkaline solution, with the heat of a water bath of about  $120^{\circ}$ . I have found ammonia the most speedy agent for this depurating process.

5568. Agreeably to the old process, oil of wine was generated towards the last. Hence, after the ether was distilled, a compound of alcohol and oil of wine remained, and could be brought over by raising the water bath to a boiling heat. Hoffman's anodyne liquor was thus obtained.

*Of heavy Oil of Wine, denominated by Liebig, "the double Sulphate of the Oxide of Ethyl and Etherole," the true Sulphuric Ether,  $C^4 H^8 O + C^4 H^4 + 2SO^2$ : also of light Oil of Wine.*

5569. When the proportion of sulphuric acid, in the mixture of this acid and alcohol employed to produce ether, becomes sufficient to retain the ether until the temperature rises above  $324^{\circ}$ , a reaction ensues by which a yellow, sulphurous, ethereal solution of oil of wine comes over (8039) (5299). This consists of nearly equal parts of sulphurous acid and ether, the oil of wine being present only in a comparatively minute proportion. This liquid being subjected to distillation at a heat not exceeding  $120^{\circ}$ , the greater part of the ether and sulphurous acid may be brought over. The residue may then be exposed in vacuo over sulphuric acid and slaked lime. By these means all the sulphurous acid ether, and water, are absorbed, the oil of wine being isolated.

5570. *Properties.*—Thus obtained, oil of wine has an unctuous consistency, whence its name. It is transparent, nearly colourless, and highly fragrant. Its taste has a resemblance to that of peppermint.

5571. *Of the Composition of Oil of Wine.*—In the first instance, by Hennel, and afterwards more fully by Serallas, that kind of oil of wine which is designated as "heavy," was shown to be a chemical compound of sulphuric acid, carbon, and hydrogen. Subsequently, it was considered as a neutral hydrated sulphate of etherine,  $2C^4 H^4 + HO + 2SO^2$ . This, of course, contains the same elements as if it were considered as an anhydrous neutral sulphate of the oxide of ethyl,  $2C^4 H^4 O + 2SO^2$ . Lately, it has been represented by Liebig, as a double sulphate of the oxide of ethyl and etherole; this last mentioned ingredient being, in other words, etherine,  $C^4 H^4$ .

5572. Oil of wine, thus defined, has been called heavy oil of wine, because it sinks in water. It appears that it may be more or less deprived of its sulphuric acid, by being distilled from milk of lime, or by being digested with caustic alkaline solutions, and then forms what is called light oil of wine, being lighter than water. From the heavy oil, when free from water, I was unable to remove the acid entirely by distillation from potassium.

5573. When alcohol is etherified by chloride of zinc, two light oils are alleged to be evolved, one having the formula  $C^4 H^7$ , the other  $C^4 H^8$ . Being devoid of sulphuric acid, these oils are of course quite different from the heavy oil, of which the formula is above given. The allegations respecting the composition of this heavy oil, are to me quite unsatisfactory, and lead to the impression that we are still ignorant of its true constitution. Nothing can be more anomalous, and inconsistent with the laws of chemical combination, with which experience has made us acquainted, than that two atoms of an acid, being comprised within a compound, and one of them in union with an oxidized radical acting as a base, as ether does, the other should refuse to unite with another atom of that base, and yet combine with a non-oxidized radical, etherole or etherine. In its free state, this last mentioned compound unites neither with sulphuric acid, nor any other acid, and yet

it is represented as replacing the basic water, and completely neutralizing the acid properties of sulphovinic acid, so that no immediate reaction ensues on contact with the most powerful bases. It is unnecessary to repeat here the suggestions respecting the bibasic character of sulphovinic acid, made in treating of its inexplicable properties (5289).

5574. *Of Hoffman's Anodyne Liquor.*—In consequence of the innovations made in the manufacture of ether, with the view of saving the acid, agreeably to the explanations above given (5566), the genuine anodyne liquor of Hoffman, being no longer a collateral product of that manufacture, a mixture of ether and alcohol came to be substituted in commerce for the true medicine. This drew the attention of some of our older physicians, Dr. Wistar, and my late colleague, Dr. Physick. Dr. Wistar had remarked that the modern anodyne liquor did not produce any milkiness in wine, when added to it, and he observed that the presence of this appeared essential to the efficacy of the medicament. In consequence of the request of Dr. Physick, having given some attention to the subject, I ascertained that in the officinal anodyne there was generally no oil of wine, and hence nothing to be separated on the addition of water. This phenomenon was found only to ensue in the anodyne prepared by those druggists who adhered to the old method of manufacture. As both by Drs. Physick and Dewees, much value was attached to the real anodyne "*as highly useful in some disturbed states of the system, in tranquillizing and disposing to sleep,*" I regret that no efforts have been made, by those who are in the practice of medicine, to ascertain whether there is any separate efficacy in the oil of wine, or whether it operates by giving greater permanency to the impression made by ether by lessening its volatility; and if this be the case, whether other essential oils cannot be used in lieu of oil of wine, as a vehicle for ether.

5575. *A Process for making Hoffman's Anodyne.*—It has been mentioned, that when the materials employed for the generation of ether have a certain ratio, and the temperature reaches a certain height, a yellow liquid comes over, which consists of heavy oil of wine, ether and sulphurous acid. This liquid being refrigerated by ice, and mingled, gradually, with ammonia, also refrigerated in a bottle surrounded by ice water, the ethereal solution loses about half its bulk and weight. The residual liquid, which floats upon the resulting ammoniacal solution, being separated by dilution with twenty-four parts of alcohol, forms the anodyne liquor which I have been accustomed to prepare.

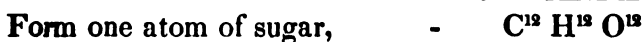
### *Of Alcohol, or the Hydrated Oxide of Ethyl.*

5576. In treating of ethyl, the theoretical composition of alcohol was, I trust, sufficiently explained (3069). I have now to treat of the means of obtaining it, and of its properties.

5577. Alcohol can only be obtained through the medium of the process called the vinous fermentation, being that by which the juice of the grape, of the apple, or pear, or infusions of sugar, or farinaceous substances, are rendered spirituous. By subjecting fermented liquors thus originating, to distillation, alcohol, diluted with water, and

flavoured by various peculiar empyreumatic oils, is obtained, being known as brandy, rum, or whiskey, accordingly as it may be derived from wine, from molasses, or from grain or cider.

5578. The vinous fermentation may be induced by the addition of yeast to a solution of sugar, kept between  $60^{\circ}$  and  $70^{\circ}$ . During this process, a new distribution of the elements takes place, so as to form alcohol and carbonic acid. One atom of dry grape sugar,  $C^{12}O^{12}H^{12}$ , is converted into two atoms of alcohol,  $2(C^4H^5O + HO)$  and four atoms of carbonic acid,  $4CO^2$ .



5579. It can hardly be necessary to mention, that the intoxicating power of the various liquids known generally in commerce as spirits, as well as that of wine, beer, cider, and other fermented liquors, is due to the alcohol which they contain. These spirits, whether known as whiskey, gin, rum, brandy, or arrack, in a chemical point of view, may be considered as mixtures of water with alcohol. Proof spirits is a term applied to any of these mixtures, when consisting of their principal ingredients in equal proportion.

5580. When, in consequence of the request of the British treasury department, a committee of the Royal Society undertook to make a table, showing the relation between the density and the quantity of alcohol in a series of mixtures of this liquid and water, though the most scrupulous accuracy was displayed, the conclusion was adopted, that the matter existing in the various kinds of spirit, on which their diversity as respects flavour and value is dependent, was too small to require to be taken into account. Nevertheless, it is well known that peculiar volatile oils accompany the whiskey obtained from grain and potatoes; and Ure alleges, that spirit obtained from damaged grain, has been found to contain a peculiar volatile matter augmenting its intoxicating power, so as to produce in some persons a sort of frenzy. This matter, at the end of a few months, was spontaneously decomposed, so as to render the spirit less nauseous and unwholesome. The

impression which has existed in this country, that brandy is more unwholesome than other spirituous liquors may depend on an analogous cause. I am under the impression that brandy and rum contain principles which cause their peculiar flavour, and that the difference between old and new spirit, is due to the modification of those essential oils on which the peculiarity of quassia in such cases dependent.

5581. By distilling one-half of the volume from monardella spirit, officinal spirit of wine is procured, and by a second rectification, a liquid of the density 0.825 may be obtained still containing eleven per cent. of water. But it is not possible for the vapour of any liquid to be formed in the presence of another liquid, without becoming associated with a portion of its vapour. Besides, the inferior density of aqueous vapour creates in it a tendency to rise with the vapour of alcohol, as hydrogen does in atmosphere. Hence the presence of two or three per cent. of water is alleged, makes the boiling point of alcohol lower. Consequently, a more aqueous portion distils first under the same circumstances. But on the other hand, when the proportion of water reaches to six per cent., the result is inverted, so that the product, which first comes over, is more aqueous than the subsequent product. According to the reasoning, if the capital of the still be kept at  $174^{\circ}$ , no water which contains less than ninety per cent. of alcohol will pass over. Of course, the same object would be obtained by passing the beak of one retort into the tubulure of another quite empty, and preserving the latter at a low temperature, while its beak is made to communicate with a receiver properly refrigerated.

5582. Alcohol may likewise be concentrated by being subjected, in a well cleansed bladder, to the temperature of  $122^{\circ}$ . The bladder is made more efficient by being smeared with a solution of gelatine, four times inside and twice outside.

5583. But to procure absolute alcohol, or, in other words, that which is devoid of water, a resort must be had to a chemical agent having a great affinity for water. Recently ignited carbonate of potash, quick-lime, or anhydrous chloride of calcium, may be employed. In either case, the spirit must be kept in contact with the substance employed for some time before distillation. Chloride of calcium, however,



is fused, is generally preferred. Of the spirit of wine more than 0.833 in density, and of the chloride of ammonium, equal weights being mixed so as to form a saturated solution by the distillation of this and a well condensed refrigerator, half the volume of absolute alcohol can be obtained. In this state it has a specific gravity, according to Ure, of 0.791 at 68°.

34. Alcohol has a very powerful affinity for water, so as to absorb it from the atmosphere, and from organic substances in general. It is by neutralizing water that it preserves anatomical preparations, performing, in this respect, a part analogous to that of brine. As the freezing point of mixtures of this liquid with water is extremely low, when added to snow, it operates as deliquescent salt, and produces cold (419). The opposite effect results from its union with water, as it forms in that case a liquid, of which the capacity for heat is less than the sum of the capacities of the ingredients. Alcohol, by combustion, yields only water and carbonic acid. It is more expansible than water and boils at 176°. Its capacity for heat, whether in liquid or æriform state, is much less than that of water. It is a powerful solvent, and highly useful agent in pharmacy, and in the delicate analysis of vegetable and animal matter. There is no satisfactory evidence that alcohol has ever been frozen. The most intense cold produced by solid carbonic acid and ether, by Dr. Mitchell, did not become syrupy in consistence, but did not freeze it. The addition of one-seventh of oil of turpentine renders the flame of alcohol so luminous, as to be a convenient substitute for a candle flame. When alcohol is passed through a red-hot porcelain or copper tube, it is decomposed into water and carburetted hydrogen.

*Of Ethero-sulphurous Acid, or Sulphurous Ether.*

5. Although no definite compound of sulphurous acid with the oxide of copper has been made, an affinity exists between this acid and oxide, resembling that between alcohol and water. Sulphurous acid boils at  $-12^{\circ}$ , at 98°, the difference being 110°. Of course, were not the affinity between these fluids more energetic than that between alcohol and water, of which the boiling point differs only by 36°, they would not remain united at very high temperatures. The boiling point of sulphurous ether is lowered, in proportion as the ratio of the acid to the sulphuric ether is increased. If it contains oil of wine, the temperature necessary to ebullition of the mixture is inversely as the quantity of the sulphurous acid, and directly as the quantity of the oil of wine, to the quantity of the other ingredient. Hence,

although I have obtained sulphurous ether, which boils at  $28^{\circ}$ , it is not possible, with the heat of a boiling water bath, to separate the last portion of this ether from the oil of wine, since a part of the latter distils with it. I kept twenty-six measures of the compound of sulphurous ether and oil of wine in a glass measure, over water, for three weeks, without the slightest perceptible diminution of the quantity of the former. By means of a stopple secured by screws, about an ounce of the volatile sulphurous ether was kept in contact with water for more than six weeks without apparent alteration. Even when in contact with ammonia, the transfer of the acid from the ether to the alkali takes place slowly, unless agitation be employed.

5586. *Of Hyponitrite of the Oxide of Ethyl, Hyponitrite of Ethyl, Nitrite of Ethyl, Nitric Ether, Nitrous Ether,  $C^4H^5O + NO^3$ .* This ethereal compound is generated by the mixture of alcohol with nitric acid, provided the concentration and proportion of the latter and the temperature, be such as to prevent the reaction from being too violent; in which case the products are liable, according to Liebig, to be carbonic, acetic, and formic acid, with acetic and formic ether. This distinguished chemist omits to mention the residual elements of the nitric acid employed. From the copious display of red fumes, there seems to be reason to infer that nitrous or hyponitrous acid is abundantly evolved. It is alleged by the same author, that when the reaction is sufficiently mitigated by the dilution of the reagents, and moderation of the temperature, only aldehyde and hyponitrous ether are generated.

5587. Of this I presume the following rationale may be given:—From an atom of the acid employed, two atoms of oxygen, uniting with two of the hydrogen of an atom of the alcohol, convert it into aldehyde. Meanwhile three atoms of oxygen, remaining united with one of nitrogen, in the state of hyponitrous acid, combine with an atom of the oxide of ethyl, expelling the water by which it was enabled to exist as alcohol. It follows, that at a minimum, one-half of the alcohol must be destroyed.

5588. According to Liebig, the best process for the generation of this ether, in purity, is to impregnate alcohol with the vapour resulting from the reaction of nitric acid with starch, passing the æriform proceeds through a well refrigerated tube to a receiver in a similar state. I have repeated this process twice, and have found a very small quantity of pure ether to be produced, with comparatively large consumption of the materials.

**5589.** I conceive that the best process is that of which I gave an account about four years ago, and which is as follows:—

**5590.** Fourteen parts of the hyponitrite of soda with just enough water for its solution, seven parts of alcohol, eight of sulphuric acid diluted with twelve parts of water, are to be refrigerated, and introduced into a bottle immersed completely in water. In a very short time, hyponitrous ether will be seen swimming on the mixture; and after about six hours the process will be so far perfected, as to make it expedient to decant the ether.

**5591.** In lieu of including the materials within a bottle, as above described, the salt, previously dissolved in water, may be introduced into a tubulated retort, with a beak recurved and adapted to a refrigerating apparatus and receiver surrounded by ice-water, as already described. Through the tubulure of the retort, a tapering glass tube, terminating in an orifice of about a tenth of an inch in diameter, should descend nearly to the bottom, being secured air-tight to the tubulure by gum elastic or other luting.

**5592.** The alcohol, acid, and water, being united and quite cool, may now be poured in through the tube; the ether rapidly generated is condensed in the receiver in a state quite free from aldehyde. Water containing a very little lime, potash, soda, or ammonia, may be used to free it entirely from acid, and quick-lime to free it from water.

**5593.** Hyponitrous ether, thus obtained, differs from the ether ordinarily known as nitric or nitrous ether, in having a more bland and saccharine taste, milder odour, and greater volatility. It boils below  $65^{\circ}$  F., and, by its spontaneous evaporation from the bulb of a thermometer, produces a cold of  $15^{\circ}$  below zero, F. Touched with the finger or tongue, it hisses as does water with a red-hot iron.

**5594.** If, after having boiled for some time, it be allowed to stand for a while at a temperature below its boiling point, the boiling will recommence at a lower temperature than that which was indicated by the thermometer when the boiling ceased.

**5595.** This seems to arise from the partial re-solution of the ether into an ethereal gas, which appears to be formed by the materials by which the liquid ether is generated, even when refrigerated below the freezing point. I have collected this æriform ether, in large quantities, in bells over mercury. When subjected to great pressure, it condenses, more or less, into a yellow liquid, which produces, when allowed to escape into the mouth or nostrils, the same impression as the liquid ether. I have conjectured that this ether might be a compound of the liquid ether with nitric oxide gas, or that it may be isomeric with the liquid ether. Notwithstanding many efforts to obtain a liquid ether not resolvable partially into this gas, I have never succeeded. Hence the boiling point is extremely variable, as I have seen bubbles escaping below  $40^{\circ}$  from the liquid ether, when recently condensed after distillation.

**5596.** In the production of cold by mixture with solid carbonic acid, Dr. J. K. Mitchell found this ether more efficacious than that commonly known as sulphuric ether, more properly called hydric ether.

**5597.** When the new ether, as it is first evolved, is distilled from powdered quick-lime, this earth imbibes an essential oil, which, with the aid of water, is yielded to pure hydric ether. Of course, it is easy to remove this solvent by evaporation or distillation.

5598. The odour of this oil seems to be an ingredient in that of nitric ether. Possibly the hyponitrous ether may resolve itself into this oil and the gaseous ether, so that its boiling point may be varied by this chemical change. I suspect that the essential oil is one of the impurities which causes the boiling point of the ether, by nitric acid and alcohol, to be higher than the boiling point obtained, as in my process, by nascent hyponitrous acid.

5599. When the heat is raised, after the volatile ether ceases over from the materials above mentioned as producing it, ethereal are distilled, of which the boiling point gradually rises as the proceeds. Meanwhile, the product thus obtained, becomes more acrid, till at last it is rendered insupportable to the tongue, as res after taste. On mingling these liquids with a solution of green iron, the ether is all absorbed; but an acrid liquid, which causes taste, is not absorbed, and may be separated by hydric ether. being vaporized by heat, the acrid liquid remains. The smaller this liquid is productive of an effect upon the organs of taste and that of mustard or horse-radish.

5600. The new ether, when secured in a glass phial by means ground stopper, does not undergo any change by keeping in a cork for several months. A phial was suspended about fifteen feet surface of the ground, in a cistern of water, for about five months was left in a cool cellar for a longer period, without any apparent change of properties. In this case pressure prevented the escape of the ether as above mentioned.

5601. All the ethereal compounds formed by the reaction of nitrogen with alcohol appear to be decomposable by green iron. Under these circumstances, according to Berzelius, a malic acid is formed from common nitric ether.

5602. Concentrated sulphuric acid absorbs the elements derived from alcohol, and liberates nitric oxide gas, which is, it is well known, absorbable by the green sulphate above mentioned. Let there be two cylindrical glass jars, of such a ratio to each other in size, as to allow of interstices of about half an inch between the second or intermediate and the outer and innermost jar; likewise, let two bell-glasses be prepared of such a size as that one of them may enter the inner interstice, the other will cover and descend into the outer interstice. Let a vessel containing the ether, be placed in the innermost jar, and let the vessel be supplied with green sulphate of iron, the other two with concentrated sulphuric acid, and let the bells be put in their respective places.

5603. Under these circumstances, the ether will be gradually absorbed, and the alcoholic elements, with some oxygen, will be absorbed by the iron, while nitric oxide, being liberated, will pass into the sulphate, and consequently, be absorbed.

### *Of the Process for Sweet Spirit of Nitre.*

5604. This name is applied to a dilute solution of pure hyponitrous ether in alcohol, which has acquired its name from being obtained by subjecting nitre and sulphuric acid to distillation with a great excess of alcohol in proper proportions, agreeably to the United States Dispensatory.

pounds of nitre, one and a half pounds of acid, nine of alcohol, the product being rectified from a proof spirit and an ounce of carbonate of potassa. The spirit of nitre of commerce is a very uncertain to the nature and proportion of its ingredients, has been informed by eminent druggists, as well as by chemists. By keeping, it becomes partially acidified, and I have kept pure hyponitrous ether in a cool cellar nearly a year without deterioration. I am of opinion it would be advantageous if the prescriptions of physicians were made with reference to ingredients of proof of purity. The physician should know how much ether is contained in the diluted article which he directs his patient to use. Hence the pure hyponitrite of ethyl should be prescribed, adding as much alcohol or water as may be deemed necessary. Agreeably to the present practice, it is in the power of manufacturing to impoverish ethereal preparations with little detection.

Pursuant to the London Pharmacopœia, three parts of nitric acid, by distillation with a quart of alcohol, are allowed to produce twenty-four fluid ounces of ether of nitre. According to Thenard, the quantity of alcohol when the materials are in the ratio of equality, is only two-thirds the weight of the acid. Hence it is that the quantity of ether in twenty-four fluid ounces of sweet spirit of nitre, obtained as above mentioned, is not more than two ounces. I infer that sweet spirit of nitre, of a more uniform strength, would be obtained by the addition of alcohol to pure nitric ether, to an amount more than adequate to render it soluble in water, and by adding water to the alcoholic solution, until the ether would form only a twelfth of the aggregate. In a proportion thus made, the properties of the ether would be necessarily associated with those of alcohol, as in an official preparation.

*Perchlorate of the Oxide of Ethyl, or Perchloric Ether.*

This ether was discovered, in my laboratory, by Mr. Martin Boyé and Mr. Hare.

It was obtained by subjecting about ninety grains of crystallized potassium baryta, with an equivalent proportion of perchlorate of baryta, to a distillatory process, receiving the product in from one to two parts of absolute alcohol. By complex affinity, the sulphuric acid of the

sulphovinate dispossesses the perchloric acid of the baryta, while, at the same time, the last mentioned acid combines with the oxide of ethyl.

5608. The perchlorate of ethyl is a transparent, colourless liquid, possessing a peculiar, though agreeable smell, and a very sweet taste, which, on subsiding, leaves a biting impression on the tongue, resembling that of the oil of cinnamon, but more acrid and enduring. It is heavier than water, through which it rapidly sinks. It explodes by ignition, friction, or percussion, and sometimes without any assignable cause. Its explosive properties may be safely shown, by pouring a small portion of the alcoholic solution into a small porcelain capsule, and adding an equal volume of water. The ether will collect in a drop at the bottom, and may be subsequently separated by pouring off the greater part of the water, and throwing the rest on a moistened filter, supported by a wire. After the water has drained off, the drop of ether remaining at the bottom of the filter may be exploded either by approaching it to an ignited body, or by the blow of a hammer. The violence and readiness with which this ether explodes is not surpassed by that of any other known compound. By the smallest drop, an open porcelain plate may be reduced into fragments, and by a larger quantity, to powder. In consequence of the force with which it projects the minute fragments of any containing vessel in which it explodes, it is necessary that the operator should wear gloves, and a close mask, furnished with thick glass-plates at the apertures for the eyes, and perform his manipulations with the intervention of a moveable wooden screen.\*

5609. In common with other ethers, the perchlorate of ethyl is insoluble in water, but soluble in alcohol; and its solution in the latter, when sufficiently dilute, burns entirely away without explosion. It may be kept for a length of time unchanged, even when in contact with water; but the addition of this fluid, when employed to precipitate it from its alcoholic solution, causes it partially to be decomposed. Potassa, dissolved in alcohol, and added to the alcoholic solution, produces immediately, an abundant precipitate of the perchlorate of that base, and, when added in sufficient quantity, decomposes the ether entirely.

5610. The perchlorate of ethyl has been subjected to the heat of boiling water without explosion or ebullition.

5611. It may be observed that this is the first ether formed by the combination of an inorganic acid containing more than three atoms of oxygen with the oxide of ethule, and that the chlorine and oxygen in the whole compound are just sufficient to form chlorohydric acid, water and carbonic oxide with the hydrogen and carbon. It is also the only ether which is explosive per se.

#### *Of Acetic Ether, or Acetated Oxide of Ethyl, $C^4 H^8 O^3 + C^4 H^8 O$ .*

5612. In common with other oxacid ethers, this ether may be obtained agreeably to the principles already set forth (5303), by distilling alcohol and sulphuric acid, or in other words, sulphovinic acid, with any acetate, or any sulphovinate with concentrated acetic acid.

5613. Acetic ether is colourless, burns readily with a pale yellow flame, has a refreshing odour, with a density of 0.890 at 60°. It boils at 165°, does not redden litmus, is soluble in seven parts of water, and in every pro-

\* For the particulars of the process I refer to the American Philosophical Transactions, Vol. 8, New Series; also to Silliman's Journal, Vol. 42, for 1842, page 62.

on in alcohol or ether. In general it is a solvent of all the substances which dissolve in this last mentioned liquid. By alkalis it is readily imposed, likewise by sulphuric acid by which it is resolved into ether and acetic acid.

*f Oxalic Ether, or Oxalated Oxide of Ethyl,  $C^4 H^4 O + O^4 H^4 O^2$ .*

614. This ethereal compound, discovered by Thenard, may be obtained by the following process:—Four parts of binoxalate of potash are mixed in a retort, with five parts of oil of vitriol, and four parts of alcohol, of  $840^\circ$ , briskly distilled. As soon as the product becomes turbid on the addition of water, the receiver is changed. The subsequent product being quickly mixed with four times its bulk of water, the ether sinks to the bottom.

It should be separated and washed with successive portions of water, till it becomes neutral to test paper. The ether thus washed is transferred to a small dry retort, filled up to nine-tenths of its capacity, and rectified. As soon as the product becomes clear, and the boiling goes on, regularly, the receiver is changed. What now passes over is pure anhydrous oxalate of ethyl (oxalic ether)—(Ettling). It is a colourless, transparent, oily fluid, of sp. g. 1.0929 at  $46^\circ$ , boiling at  $370^\circ$ , miscible with alcohol and ether, and having a peculiar aromatic smell. In a state of purity it may be kept many days under water, in which it is very sparingly soluble without decomposition; but when it contains but a minute proportion of water or acid or alcohol, it is speedily decomposed into oxalic acid, which is separated in large four-sided prisms, and alcohol. The same reaction ensues in an excess of fixed alkali.

*f Carbonic Ether, or Carbonated Oxide of Ethyl,  $C^4 H^4 O + CO^2$ .*

615. Discovered by Ettling by the following means:—Fragments of potassium being added to oxalic ether, duly warmed, as long as any gas is evolved and any excess of the metal removed, the resulting mass was submitted to distillation. Carbonic ether was generated, and being conveyed into the receiver, formed a superstratum upon the other products of the process. Being separated, and freed from water by the chloride of calcium, and redistilled from potassium till, on contact with caustic potash, no oxide could be formed.

616. Carbonic ether is colourless, ethereal, and very liquid, having an aromatic taste, and an aromatic odour, resembling the ether from which it is generated. It is lighter than water, has the specific gravity 0.975 at  $66^\circ$ , and at  $260^\circ$ , and burns feebly with a blue flame. It may be mingled in various proportions with alcohol and ether, but is insoluble in water. When mixed with an alcoholic solution either of the hydrate of potash or soda, it is quickly resolved into alcohol and an alkaline carbonate, which separates from the water as an oily concentrated solution, or forms as a crystalline powder, if water be present. The formation of carbonic ether, which is attended with the production of several substances not yet examined, is still unexplained.

*Formiated Oxide of Ethyl, or Formic Ether,  $C^4 H^4 O + C^2 H^2 O^2$ .*

617. To prepare formic ether, seven parts dry formiate of soda are dissolved with ten parts of sulphuric acid, and six of alcohol, of about  $830^\circ$ .

618. Formic ether is generated, and comes over for the most part without the application of heat. It is depurated of acid by milk of lime, and

from water by chloride of calcium, which should be added so long as it becomes moist (5281).

5619. Formic ether is a limpid liquid, of a penetrating, aromatic odour, being of the density of 0.912. It boils at 128. Its taste is cooling and spicy. It requires for its solution ten parts of water, but dissolves in all proportions in alcohol and ether, in pyroxylic spirit and several fixed and volatile oils. It is acidified by exposure to air.

*Of Benzoated Oxide of Ethyl, or Benzoic Ether,  $C^{14}H^5O + C^6H^5O$ .*

5620. This ether, discovered by Sheele, and analyzed by Wöhler and Liebig, is generated by distilling a mixture of four parts of alcohol, of 88°, two parts of crystallized benzoic acid, and one of concentrated, liquid, chlorohydric acid. As soon as the product renders water turbid, the receiver should be changed, as what passes over subsequently is benzoic ether. The ether, thus obtained, must be added to water to separate it, and be afterwards boiled, with water and litharge, to remove free benzoic acid, and lastly, digested with chloride of calcium.

5621. Benzoic ether is colourless, neutral, and very liquid, having an ethereal but suffocating odour, and provoking tears. Its specific gravity, at 50°, is 1.0539. It boils at 410°, is soluble in alcohol and ether, but insoluble in water. It is decomposed by chlorine, according to Malaguti, producing, among other products, chloride of benzule.

*Of the Tartrate and Citrate of the Oxide of Ethyl, and other "Salts" of Ethyl, so called, of minor importance.*

5622. There are few oxacids which may not be united with the oxide of ethyl and other oxidized compound radicals, so as to form combinations in composition analogous to the complex ethers. Those formed with citric and tartaric acid, are hardly ethereal in their properties. The citrate requires a heat of 540° for ebullition, and is partially decomposed during distillation. The tartrate, not being capable of neutralization, is more a congener of sulphovinic acid, viewed as a bibasic acid (5290), than of the complex ethers (3079).

5623. I shall forbear to treat of various compounds, analogous in composition to those above described, whether having the oxide of ethyl, or any other oxidized compound radical, as a base, for reasons like those already given in relation to the acids (5397).

*Of Ceanthated Oxide of Ethyl, or Ceanthic Ether,  $C^4H^5O + C^{14}H^{10}O$ .*

5624. This liquid is called ethereal oil of wines, by Graham, which tends to confound it with the oil of wine, Liebig's sulphate of ethyl and etherole. It is alleged to be the cause of the characteristic odour by which wines are generically distinguished from dilute alcohol. It forms a portion of the residue of the distillation of brandy from wines in the large way. It is said to constitute about one part in 40,000 of wine. The bouquet by which some wines are distinguished, ought to be ascribed to this ethereal compound.

5625. Ceanthic ether is a colourless liquid, having an intense odour of wine, almost intoxicating when plentifully inspired, and a strong disagreeable taste. It is soluble in ether and in alcohol, whether concentrated or dilute; but not in water. Its density is 362; its volatility feeble. It requires a temperature between 434 and 446 for ebullition. This ether is instantly decomposed by fixed caustic alkalies; but not by ammonia, or



carbonates. When distilled with caustic potash, it is resolved into which comes over, and a very soluble cyanthate of potash.—Gravimetric elements.

*Alc. Ethers, formed by the Substitution of another Basicigen Body for the Oxygen in the Oxide of Ethyl; or for the Hydrogen in the Water with that Oxide.*

*Chloride of ethyl*,  $C^4 H^5 Cl$ , also called *chlorohydric ether*, *formic ether*.—It must be evident, from the comparison of the former given, with that of ether,  $C^4 H^5 O$ , that this chloride differs from the oxide, only in the substitution of an atom of chlorine for an atom of oxygen.

Chloride of ethyl is generated by the distillatory reaction of chlorohydric acid, or various chlorides, either with the oxide of ethyl, with alcohol, or any other of the compounds of that oxide, such as acetic, citric, tartaric ether, &c. Agreeably to one process, alcohol is to be first saturated with chlorohydric acid gas; according to another, it should be mixed with an equivalent proportion of a strong aqueous solution of that acid. The means of a glass retort, communicating by a tube with some water, at a temperature of about  $90^\circ F.$ , in a bottle with three orifices. Through the first orifice, the tube proceeding from the retort enters, and is luted air-tight; through the second orifice, a tube of safety is inserted; from the third orifice another tube, arranged so as to communicate, through a refrigerating mixture, with the interior of a phial surrounded by a freezing mixture. The intermediate vessel detains any alcohol or acid evolved, while the ether, which, in consequence of its greater volatility, reaches the receiver. The product is freed from water and alcohol by digestion, for twenty-four hours, on chloride of calcium, cooled by ice-water.

Chloride of ethyl is a colourless, ethereal liquid, with an aromatic, pungent, and somewhat alliaceous odour. Its density is .874 at  $41^\circ F.$  at  $52^\circ$ ; does not redden litmus; dissolves in twenty-four parts of ether, producing a solution which has a fresh, aromatic taste. With silver it gives no precipitate. It burns with a bright flame, green at the base, evolving fumes of chlorohydric acid. In passing through an absorption tube, it is resolved into equal volumes of that acid, and olefiant gas. The exposure of this chloride to gaseous chlorine, aided by the solar rays, gives rise to a series of compounds. It is decomposed after some time by the alkaline hydrates, into a chloride of the ingredient metals, and alcohol.

*Bromide of ethyl*,  $C^4 H^5 Br$ , was discovered by Serullas, by distilling a mixture of one part of bromine, four of alcohol, and one-eighth of phosphorus. It is a colourless liquid, denser than water, and very volatile.

*Iodide of ethyl*,  $C^4 H^5 I$ , may be obtained by distilling alcohol, saturated with hydriodic acid gas. It is a colourless liquid, of the density 1.86. It boils at  $161^\circ F.$

*Sulphide of ethyl*,  $C^4 H^5 S$ , is formed by transmitting the vapour of chlorohydric ether, through an alcoholic solution of the proto-sulphuret of potassium; the chlorine being precipitated with the potassium, the sulphide with the ethyl and is dissolved, or distils over, if kept sufficiently warm. It is a colourless liquid; the boiling point,  $135^\circ$ ; density, 1.268.

5632. *Sulphydrate of the Sulphide of Ethyl, or Mercaptan*,  $C^4 H^5 S + HS$ .—It might be advantageously called *sulphalcohol*, since sulphur performs in it the part allotted to oxygen in alcohol proper, sulphydric acid occupying the place of water, as may be perceived by the name and formula.

5633. The best way to prepare this compound, discovered by Zeise, is to distil a solution of the sulphovinate of lime, of the density of 1.28, with a solution of sulphydrate of the sulphide of potassium, generated by saturating a solution of potash, also of the density of 1.28, with sulphydric acid gas.

5634. The product may be condensed by means of a refrigerating apparatus, like that mentioned as having been used for ether (5567). It may be purified from an excess of sulphydric acid, alcohol and water, by a second distillation from a small quantity of red oxide of mercury, and subsequent digestion with chloride of calcium. Mercaptan boils at  $100^\circ$  ungly, being a colourless, ethereal liquid, with a most penetrating and insupportable alliaceous odour. Its density is said to be 0.835 at  $70^\circ$ , and 0.842 at  $59^\circ$ . It is soluble in alcohol and ether, but it is very slightly soluble in water. The sulphydric acid of mercaptan reacts powerfully with metallic oxides, generating water, and a sulphide of the metal. This sulphide remains in combination with the sulphide of ethyl, thus forming a class of sulphur salts. The oxide of mercury is instantly converted, by mercaptan, into a compound of this class, the mercaptide of mercury,  $C^4 H^5 S + Hg S$ , which is a white, crystalline mass, soft to the touch, without odour, insoluble in water, and fusible, like wax, at  $185^\circ$ . This mercaptide when distilled leaves cinnabar, and affords a volatile liquid, which has not been examined. The oxide of gold is also strongly acted on by mercaptan; but other metallic oxides are less affected in proportion as they are more electro-positive. Thus, the hydrates of potash and soda have no sensible reaction with mercaptan. When gently heated, with nitric acid, mercaptan is converted into a new acid, which contains sulphide of ethyl, and the elements of sulphuric acid,  $C^4 H^5 S^2 O^2$  (Læwig, Kopp).

5635. *Bisulphide of ethyl*,  $C^4 H^5 S^2$ .—A transparent, oily liquid, which boils at  $123.5^\circ$ , is obtained by distilling a mixture of sulphovinate of potash and the persulphide of potassium. It is decomposed by caustic potash, or by nitric acid (Zeise, Pyrame, Morin).

5636. *Selenide of ethyl* is obtained, according to Læwig, in the same way as the sulphide, substituting in the process, selenide of potassium for the sulphide of potassium.

5637. *Telluride of ethyl*,  $C^4 H^5$ , a very volatile liquid, of a deep orange colour (Whøler), may be obtained also by a similar process, using the telluride of potassium.

5638. *Cyanide of ethyl*, improperly called *cyanhydric ether*,  $= C^4 H^5 N$ , is a colourless liquid, with an insupportable odour of garlic, was obtained by Pelouze, by exposing a dry mixture of sulphate of ethyl and potash to a gentle heat, gradually increased. It has also been formed by distilling a mixture of sulphocyanide of potassium, alcohol, and sulphuric acid. It is a thick, oily liquid, of the density of 0.7, boiling at  $179.6^\circ$ .

*Of the Dehydrogenation and Oxidation of Ethyl, as contained in Ether or Alcohol, and of the Oxidation of the residual Products.*

5639. The precipitation of carbon which gives a fuliginous character to the flame of essential oils and resins, has been ascribed to an inadequate supply of oxygen, and the superior affinity of hydrogen for oxygen, comparatively with carbon, at moderate temperatures. In consequence of this preference thus given, when some of the compounds of ethyl are subjected to oxidating agents, in processes below the temperature of ignition, more or less hydrogen is removed according to the intensity of the reaction. Thus, from alcohol  $C^4H^5O + HO$ , two atoms of hydrogen being taken, aldehyde is engendered,  $C^4H^3O + HO$ . These elements, by the absorption of one atom of oxygen, form an acid which has been called aldehydic acid, or acetous acid,  $C^4H^3O^2 + HO$ . Another atom of oxygen converts this acid into acetic acid,  $C^4H^3 + O^2 + HO$ . Aldehydic acid has also been designated as acetous acid, having the same radical, and less oxygen than acetic acid (3094).

5640. *Acetyl*, of which the formula is  $C^4H^3O$ , has been already described as a compound radical, indebted for its existence to the removal of two of the five atoms of hydrogen belonging to ethyl (3093). Liebig attributes this result to the *oxidation* of the ethyl; but it is, as I conceive, a case of *dehydrogenation* of ethyl, resulting from the oxidation of two-fifths of its hydrogen. The relation between this radical and its progeny may be seen in the following table.

Acetyl,	-	-	-	-	$C^4H^3$
Aldehydic, or hydrate of the oxide of acetyl,	-	-	-	-	$C^4H^3O + HO$ .
Acetous, or aldehydic acid,	-	-	-	-	$C^4H^3O^2 + HO$ .
Acetic acid,	-	-	-	-	$C^4H^3O^3 + HO$ .

No oxide of acetyl has been ascertained to exist uncombined with water and corresponding to common ether.

*Of the Hydrated Oxide of Acetyl, called Aldehyde.*

5641. By inspection of the respective formulæ, it will be perceived, that this compound differs from alcohol only

in the loss of two atoms of hydrogen. Hence its name from the first syllable of each of the words *alcohol* and *dehydrogenatum*. Aldehyde is one of the products of the decomposition of alcohol, or ether, by passage through a tube at a low red heat: during etherification by nitric acid (5586): by platina wire in the lamp without flame, and in other cases. Liebig's process for the preparation of aldehyde is as follows:—Six parts of oil of vitriol with four of water; four parts of spirits of wine and six of black oxide of manganese, are to be distilled with a very gentle heat, and the product collected in a receiver surrounded with ice-water. This process is completed as soon as the materials in the retort cease to froth up. Kane observes that a purer product may be obtained by distilling two parts of spirits of wine with three of bichromate of potash, three of oil of vitriol, and six of water; the two last being previously mixed and allowed to cool. To obtain aldehyde absolutely pure, it must be combined with ammonia; the resulting crystallized ammoniacal compound must afterwards be decomposed by dilute sulphuric acid, distilled, by means of a water-bath at  $120^{\circ}$ , with great care, and finally rectified over fused chloride of calcium.

5642. Aldehyde is a colourless, inflammable liquid, of a peculiar ethereal and suffocating odour. It boils at  $72^{\circ}$ , has the density 0.790 at  $64.40$ , and is soluble in water, alcohol and ether. By absorbing atmospheric oxygen, it is converted spontaneously into acetic acid. It dissolves phosphorus, sulphur and iodine. Aldehyde is capable of combining directly with ammonia and potash, thus evincing an approach to the acid character.

5643. *Ammoniated Aldehyde, or the Hypoacetite of Ammonia*,  $C^4H^3O, NH^3 + HO$ . In this compound aldehyde appears to act as an acid in entering into union with the oxide of ammonium (1106), so that it might be consistently designated as hypoacetic acid. Ammoniated aldehyde crystallizes in acute, colourless, transparent, brilliant, friable rhomboids, of a considerable magnitude, and which have an odour of spirit of turpentine. These crystals fuse between  $150^{\circ}$  and  $172^{\circ}$ , and distil without decomposition, at  $212^{\circ}$ . They burn with a yellow flame. In the air, or even in closed phials, they turn brown, acquiring the smell of a burnt feather. Under pure ether they may be preserved, but not for a long time. These crystals are soluble in

water in all proportions, and more readily in hot than in cold alcohol. In ether they are but little soluble.

5644. *Acetal, a compound of aldehyde with ether*,  $C^4 H^4 O + C^2 H^4 O + HO = C^6 H^8 O^5$ , was discovered by Dobereiner, and described as oxygenated ether. It is formed by the reaction of platinum black with the vapour of alcohol, with the presence of oxygen. Acetal is a colourless liquid, having a peculiar odour, suggesting that of Hungary wines. It boils at  $803^\circ$ ; its density is 0.823 at  $68^\circ$ . It is soluble in six or seven parts of water, and mixes with alcohol in all proportions.

5645. The crude formula of acetal being  $C^6 H^8 O^5$ , two atoms of it will be found to contain the ingredients of three atoms of ether, and one of acetic acid.

5646. *Resin of aldehyde* is a product of the decomposition of aldehyde by alkalis, with the assistance of air.

5647. *Elaldehyde*.—When pure anhydrous aldehyde is kept for some time at  $32^\circ$ , while gradually losing its power to mix with water, it is transformed into a coherent mass of long, transparent, needle-shaped crystals, resembling spiculæ of ice. This is *elaldehyde*, which is similar in composition to aldehyde, but of three times the atomic weight, judging from the density of its vapour. Elaldehyde fuses at  $35.6^\circ$ , and boils at  $201.2^\circ$ .

5648. *Metaldehyde* is another product of the condensation of the elements of aldehyde, which appears in aldehyde left for some time in a well-stopped phial, in the form of white and transparent needles, or colourless prisms, which gradually attain a certain magnitude. It sublimes at  $248^\circ$ , without fusing, and condenses in the air in snowy and very light flocks. It is insoluble in water, but dissolves easily in alcohol.

*Of some interesting Results of the substitution of Chlorine, Bromine, Sulphur, and other Basacigen Bodies, for the Hydrogen or the Oxygen in the Compounds of Ethyl and Acetyl.*

5649. *Of the Chlorohydrate of the Chloride of Acetyl, Chlorine Ether, Bichlorine Ether*,  $C^4 H^3 Cl + Cl H$ .—Under the head "*olefiant gas*" (1274), it was mentioned (1292) that olefiant gas received its name from its capacity of forming a liquid of an oily consistency, having an agreeable smell and taste. On account of its resemblance to ethereal compounds, as respects fragrance, solubility and taste, and the presence in it of two atoms of chlorine, it has been called *bichlorine ether*. Considering olefiant gas as a hydruret of acetyl,  $C^4 H^3 + H$ , the liquid in question is, by Liebig, treated of under the appellation at the head of this article, which indicates it to consist of chlorohydric acid,  $CH$ , and chloride of acetyl,  $C^4 H^3 Cl$ .

5650. This liquid is usually made by the confluence of equal volumes of moist chlorine and the gas above mentioned, within a large receiver, over water. Liebig recommends the reaction of the same olefiant gas with the perchloride of antimony, so long as there is any absorption. The resulting mass is to be subjected to distillation, till the product ceases to yield any ethereal liquid on the addition of water. The combination thus elaborated, requires to be depurated by redistillation with water, and subsequent agitation with sulphuric acid to dehydrate it of moisture. This ordeal is to be repeated until it ceases to be affected by sulphydric acid, or to emit chlorohydric acid during distillation. Finally, being successively washed with water, and kept in contact with chloride of calcium, it becomes quite pure.

5651. Thus obtained, the chlorohydrate of the chloride of acetyl is colourless, very liquid, and, as respects smell and taste, sweet and agreeable. It boils at  $179^{\circ}$ . It may be distilled, without decomposition, from the alkaline hydrates. It communicates its smell to water, although insoluble therein. In alcohol and ether it dissolves in all proportions. By an alcoholic solution of potash, it is decomposed into chloride of potash and chloride of acetyl. It was by the exposure of this chlorohydrate to reaction with chlorine, in the sunshine, that Faraday (1242) obtained the esqui-chloride of carbon.

5652. *Chloride of Acetyl*.—This is a gaseous product, of which mention is above made as resulting from the reaction of its chlorohydrate with potash, in alcohol. It has an alliaceous odour, and may be liquefied at the temperature of  $-6^{\circ}$ .

5653. *Bromohydrate of Bromide of Acetyl, Bromide of Acetyl, Iodohydrate of Iodide of Acetyl*.—Substances are described by Liebig, to which these names are given, which indicate their analogy with the two compounds of chlorine last described.

5654. *Chloroplatinate of Chloride of Acetyl*.—By this name a compound has been designated, in which chloroplatinic acid takes the place of chlorohydric acid in the chlorohydrate of the chloride of acetyl.

5655. *Oxychloride of Acetyl*,  $C^4 H^3 Cl^2 O$ .—This name has been given to a colourless oily liquid, which results from the saturation of anhydrous ether with chlorine, desiccated by being passed through concentrated sulphuric acid. The formula of ether being  $C^4 H^5 O$ , two out of the five atoms of hydrogen are converted into chlorohydric acid, while two atoms of chlorine supply their place. Thus the oxychloride of acetyl is generated by a process analogous to that by which acetic acid is generated, oxygen performing, in one case, the same part as chlorine in the other.

5656. It must be evident that we have, in the formula of this compound as above given, the ingredients of acetyl combined both with oxygen and chlorine. It is therefore designated as an oxychloride, although usually this name has been applied to the union of an oxide and a chloride, each severally combined with distinct atoms of the same radical.

5657. *Oxysulphide of Acetyl*,  $C^4 H^3 S^2 O$ .—In this compound, sulphur occupies the place which chlorine fills in the oxychloride of acetyl, and of course that which oxygen fills in anhydrous acetic acid. The substitution of sulphur is effected by the reaction of the oxychloride of acetyl with sulphydric acid; during which, the two atoms of chlorine uniting with the two of hydrogen, two atoms of sulphur supply the place of the chlorine thus removed. During this last mentioned reaction, another compound is formed, in which only one atom of the chlorine in the oxychloride is replaced by sulphur. The formula, of course, is  $C^4 H^3 Cl SO$ . The ethyl in acetic ether may, by reaction with chlorine, have its hydrogen so far replaced by chlorine as to be converted into an oxychloride, while its union with the acetic acid remains unbroken. Benzoic ether may not only have its base similarly changed, but the oxygen, forming its acid with benzole, may be replaced by chlorine; so that for  $Bz O + C^4 H^3 O$ , a compound results, represented by  $Bz Cl + C^4 H^3 Cl^2 O$ .

5658. *Chloroxalic Ether*,  $C^2 Cl^3 O + C^2 O^2$ .—This ether is created by the substitution of chlorine for the whole of the hydrogen in oxalic ether, of which the formula is  $C^2 H^5 O + C^2 O^2$ . It will be seen, on comparing these formulæ, that they differ only in this; five atoms of chlorine in one are substituted for a like number of hydrogen in the other. It was obtained by

jecting oxalic ether in a retort, surrounded by boiling water and exposed to the solar light, to a current of chlorine.

5659. *Chloral*,\*  $C^4 H^3 O + HO$ , is the name given to a compound discovered by Liebig, in which all the hydrogen of aldehyde is replaced by chlorine. It might, with propriety, I think, be called hydrated oxide of chloracetyl, chloracetyl being understood to apply to the compound  $C^4 Cl^3$ , which takes the place of acetyl as the organic radical. Chloral is the immediate product of the dehydrogenation of anhydrous alcohol, by dry chlorine, and the substitution of three atoms of chlorine for five of hydrogen.

5660. By subjecting, for twelve or fifteen hours, anhydrous alcohol to chlorine, dried by passage through sulphuric acid, a copious evolution of chlorohydric acid ensues, and a dense oily liquid is generated, which condenses on cooling, being an impure hydrate of chloral. It is requisite to check the reaction in the first instance by immersion in water, afterward to assist by heat the expulsion of the chlorohydric acid. The hydrate is purified first by heating it in a well-stopped flask, with nearly three times its bulk of sulphuric acid, when the chloral, depurated of water, forms a superstratum. This being separated, and boiled to expel free chlorohydric acid, or alcohol, to remove any residual moisture, the chloral should be distilled from an equal volume of sulphuric acid. Finally, it must be freed from lime, which, after being slaked, was rendered anhydrous by exposure to a bright red heat.

5661. Chloral, thus obtained, is a dense, oily, colourless liquid, greasy to the touch, having a penetrating, disagreeable odour, which provokes sneezing. Its taste is at first greasy, then caustic. It produces on paper an acescent stain. Its density, at  $64.4^\circ$  is 1502; its boiling point is  $201^\circ$ , nearly. It may be distilled without alteration. Its vapour is nearly five times as dense as that of air, its equivalent being four volumes. Chloral is miscible either with alcohol or ether. Aided by heat it dissolves sulphur, phosphorus, or iodine, apparently without alteration.

## OF METHYL ETHERS.

### *Of the Oxide of Methyl, or Methylic Ether, $C^2 H^3 O$ .*

5662. In treating of the hypothetical compound radical, methyl, it was stated, that it was considered as performing, in the compound above mentioned, a part analogous to that which ethyl is inferred to perform in alcohol.

5663. The oxide of methyl is prepared by distilling one part of wood spirit, with four parts of sulphuric acid, the resulting gas being transmitted, successively, through a bottle containing milk of lime, and several bottles duly charged with pure water. In this liquid the gas dissolves, and being evolved by a boiling heat, may be collected over mercury. Oxide of methyl is an inflammable, colourless

\* The account of chloral, given under the head of inorganic compounds of carbon, being very brief, I have not hesitated to treat of it again, as an organic product, without reference to that imperfect notice.

gas, of an agreeable ethereal odour. For liquefaction it requires a temperature below  $3.2^{\circ}$ . Thirty-seven volumes of this gas dissolve in one of water. Alcohol, hydrated oxide of methyl, and concentrated sulphuric acid, take it up to a greater extent. From the latter it separates on dilution with water. The density of the gas is, by experiment, 1605; by calculation, 1570; its combining measure being two volumes.

5664. By combining with the vapour of anhydrous sulphuric acid, in a glass balloon, carefully cooled, the oxide of methyl forms a neutral sulphate. (Regnault.)

*Of Hydrated Oxide of Methyl, called Pyroxylic, or Wood Spirit, Methylic Alcohol,  $C^2 H^3 O + HO$ .*

5665. In the process of purifying acetic acid from wood (5199), the crude acid is saturated by lime, and concentrated by distillation, of which the first product contains the crude wood spirit, which may be partially purified by repeated distillation from quick-lime; and is found in this state in commerce. It is still a heterogeneous mixture, containing, besides the hydrated oxide of methyl, which forms the larger part of it, acetone, and several other volatile and inflammable liquids. To purify the spirit in question, it is treated with an excess of chloride of calcium, in a retort, and distilled by a water-bath heat, which expels the more volatile liquids, and leaves the wood spirit in union with the chloride of calcium. A volume of water, equal to the volume of wood spirit employed, is then added to the retort, and the distillation continued. The spirit comes over imbued with a small quantity of water, from which it may be completely separated by subsequent distillation from quick-lime (5711, &c.).

5666. Wood spirit is a volatile, colourless liquid, simultaneously recalling the taste and odour of acetic ether and alcohol. It is very inflammable, and burns with a pale flame. It mixes with pure water without becoming turbid, and likewise with alcohol and ether. Its density is 0.798 at  $68^{\circ}$ ; its boiling point,  $140^{\circ}$ . The density of its vapour is, by experiment, 1120; by calculation, 1100; its combining measure or equivalent comprises four volumes.

5667. With the aid of heat, hydrated oxide of methyl dissolves small portions of sulphur and phosphorus, and may also serve as a solvent for the resins employed in



**making varnishes.** It mixes with volatile oils. Wood spirit is, like alcohol, acted upon by chlorine, peroxide of manganese or sulphuric acid, and by oxidizing agents in general, and yields analogous products. It is also decomposed by potassium, with disengagement of pure hydrogen.

**5668.** Anhydrous barytes, although not soluble in alcohol, dissolves in pure wood spirit, with much heat, and forms a compound,  $C^2 H^3 O HO + Ba O$ , which crystallizes in needles of a silky lustre. Lime is likewise soluble in wood spirit.

**5669.** Chloride of calcium dissolves eagerly in this solvent, so as to cause much heat. From a concentrated solution, it crystallizes in large, deliquescent, hexagonal tables, which contain two atoms of hydrated oxide of methyl, united with one atom of chloride of calcium.

**5670. Neutral Sulphated Oxide of Methyl,  $C^2 H^2 SO^2$ .**—This member of the methyl series, which has no analogous compound in that of ethyl, is generated either when oxide of methyl and anhydrous sulphuric acid are brought into contact, or when one part of the hydrated oxide is distilled with eight or ten parts of sulphuric acid; the product being purified by washing with water, and distillation from chloride of calcium and quicklime, successively. Sulphated oxide of methyl is a colourless liquid, of an alliaceous odour, of density 1.324 at  $71^\circ.6$ . It boils at  $370^\circ.4$ , and may be distilled without change. The density of its vapour is 4363.4; it consists of equal volumes of anhydrous sulphuric acid and oxide of methyl, condensed into one volume; its combining measure being four volumes, the same as that of oxide of methyl. It is very slowly decomposed by water when cold, but rapidly when hot; the acid sulphated oxide of methyl and water being formed, while oxide of methyl is liberated. By double decomposition this compound may be employed in preparing all the other compounds of methyl.

**5671. Acid Sulphated Oxide of Methyl, Bisulphated Oxide of Methyl, Sulphomethylic Acid,  $C^2 H^2 O + S^2 O^2 HO$ .** This congener of sulphovinic acid, discovered by MM. Dumas and Peligot, and by Dr. Kane, about the same time, is formed by mixing concentrated sulphuric acid with hydrate of oxide of methyl; or by dissolving the neutral sulphate in boiling water. Obtained by the latter method, and concentrated by evaporation, it is a colourless, syrupy, and very acid liquid; which, in dry air, becomes a mass of white crystalline needles. It combines with bases forming double salts, in which the basic water of the acid is replaced by a metallic oxide. These double salts are soluble in water.

**5672. Nitrated Oxide of Methyl,  $Me O NO^2$ .**—To prepare this compound, one part of nitrate of potash, and a mixture of two parts of concentrated sulphuric acid with one part of wood spirit, are introduced into a retort. The mass rises in temperature, and a liquid distils without additional heat. For its condensation, a refrigerated tube should be employed, terminating in a refrigerated flask. The heavier of the two liquids found in the flask is nitrated oxide of methyl, contaminated by a portion of a very volatile compound, supposed to be formiated oxide of methyl, which imparts the

odour of cyanhydric acid. The product is rectified from chloride of calcium and from litharge. The last portions which distil over are perfectly pure. Nitrated oxide of methyl is a colourless liquid, of a weak, ethereal odour, which burns readily with a yellow flame; its density is 1.822 at  $71^{\circ}.6$ , and boiling point  $150^{\circ}.8$ . Heated above  $248^{\circ}$ , its vapour is decomposed explosively, producing carbonic acid, water, and deutoxide of nitrogen. This ether is soluble in water, and miscible in all proportions with alcohol, ether, and wood spirit.

*Of the Hyponitrite of the Oxide of Methyl, or Methylic Hyponitrous Ether, "Nitrite d'Oxide de Methyl" of Liebig, and others.*

5673. In his late Treatise on Organic Chemistry, Liebig makes the following statement:—"The reaction which nitric acid exercises with the hydrated oxide of methyl, is not like that which it exercises with alcohol, since, while this liquid is decomposed with great difficulty, giving birth to certain oxidized products and hyponitrite of the oxide of ethyl, the hydrated oxide of methyl is not altered by nitric acid, unless at a boiling heat. When a great excess of this acid is employed, formic and oxalic acid are generated, but no hyponitrite ("nitrite") nor nitrate of the oxide of methyl. It would seem, therefore, that the *hyponitrite* of the oxide of methyl does not exist." *Traite*, 552.

5674. Last winter, however, Dec. 1841, I found that by subjecting pure wood spirit to the process already described for producing the hyponitrite of ethyl, a congenous ethereal product was obtained (5583). Hyponitrite of methyl has a great resemblance to its congener above named, in colour, smell, and taste; though there is still a diversity sufficient to enable a careful observer to distinguish one from the other.

5675. When the process in which hyponitrous ether is generated, by introducing the refrigerated materials into a bottle surrounded by ice and water, was resorted to, substituting wood spirit for alcohol, it was found that the ether did not separate from the spirit as completely as in the process in which alcohol was the material. This I ascribe to the affinity between water and wood spirit being inferior to that between this last mentioned liquid and alcohol. The boiling point of both of the ethers seemed to be nearly the same, and in both, in consequence of the escape of an ethereal gas, an effervescence resembling that of ebullition, was observed to take place at a lower temperature, than that at which the boiling point became stationary.

5676. From the language of Liebig above quoted, I infer that previous efforts to produce the methylic hyponitrous ether had failed. The failure of others, and my success, cannot excite surprise, when the difference of the habitudes of wood spirit and alcohol, with nitric acid and alcohol, are taken into view, and the difference between my process and those followed in Europe, by which more or less nitric acid is brought into contact with the spirit employed. When alcohol is presented to nitric acid, a reciprocal decomposition ensues. The acid loses two atoms of oxygen, which, by taking two atoms of hydrogen from a portion of the alcohol, transforms it into aldehyde, while the hyponitrous acid resulting inevitably from the partial oxidizement of the nitric acid, unites with the base of the remaining part of the alcohol. But when pyroxylic spirit is presented to nitric acid, this acid, without decomposition, combines with methyl, the base of this hydrate: hence, as no hyponitrous acid is evolved, no hyponitrite can be produced.

Thus in the case of the one there can be no ethereal hyponitrite, in that of the other no ethereal nitrate.

5677. *Oxalated oxide of methyl*,  $C^2 H^2 O$ ,  $C^2 O^2$ , is a white, transparent, and brilliant mass, composed of rhomboidal tables, which fuses at  $123^{\circ}.8$ , and boils about  $321^{\circ}.8$ . It is decomposed by water, and resolved into hydrated oxalic acid and wood spirit.

5678. *Formiated oxide of methyl* is obtained by a process analogous to that for the formiated oxide of ethyl (5617), substituting pyroxylic spirit for alcohol. It is lighter than water, and boils between  $96$  and  $100^{\circ}$ ; its odour suggesting that of acetic ether.

*Reaction of Chlorine, Iodine, Cyanogen, and Sulphur, with Methyl and its Compounds.*

5679. *Chloride of Methyl*,  $C^2 H^2$ ,  $Cl$ .—This compound is produced by the reaction of chlorohydric acid with hydrated oxide of methyl: the rationale being the same as when this acid is presented to a hydrated metallic protoxide. But it is best obtained, as are all the halogen compounds of methyl, by distilling the haloid salt, containing the halogen body with which the union is to be made, with a mixture of sulphuric acid and hydrated oxide of methyl: of course, in the case in point, chloride of sodium may be used. Chloride of methyl is a colourless gas, of an ethereal odour and sweet taste, having the density  $1737.8$  by experiment, and  $1729$  by calculation; the combining measure being four volumes. Water dissolves  $2.8$  volumes of this gas at  $60^{\circ}.8$ . It is not liquefied by a cold of  $-0.4$ . It should be remembered that the chloride and oxide of methyl, are both much more volatile than the chloride and oxide of ethyl (873).

5680. *Iodide of Methyl*,  $C^2 H^2 I$ .—This is a colourless liquid, which inflames with difficulty, and boils between  $104^{\circ}$  and  $122^{\circ}$ . Its density is  $2.337$  at  $69.8$ .

5681. *Fluoride of Methyl*,  $C^2 H^2 F$ , is obtained by distilling sulphated oxide of methyl with fluoride of potassium. It is a colourless gas, of which the density is  $1186$ ; and, for the solution of which, fifteen volumes of water are requisite.

5682. *Cyanide of Methyl*,  $C^2 H^2 Cy$ , is an ethereal liquid, insoluble in water.

5683. *Sulphide of Methyl*,  $C^2 H^2 S$ , is a very limpid liquid, of which the odour is extremely disagreeable. Its density is  $0.845$  at  $69^{\circ}.8$ , and its boiling point  $105^{\circ}.8$ . The density of its vapour is by experiment  $2115$ , by theory  $2158$ ; its combining measure being two volumes. Sulphide of methyl is formed by double decomposition, when chloride of methyl is transmitted through an alcoholic solution of protosulphide of potassium.

5684. *Sulphydrate of the Sulphide of Methyl, or Methyl Mercaptan*, is a colourless liquid, lighter than water, which boils at  $69^{\circ}.8$  and acts on oxides of mercury and lead like sulphydrate of sulphide of ethyl.

5685. Compounds having methyl for their radical, correspond so closely with those in which ethyl sustains the same character, that knowing the history of one class, it is easy to imagine the properties of the other. Anhydrous metallic salts do not alter them, while the hydrated alkalies disengage hydrated oxide of methyl from them with great facility.

5686. Chlorine decomposes the gaseous oxide of methyl, forming chlorohydric acid, and the following products, as observed by M. Regnault:—

Monochlorinated oxide of methyl,       $C^2 H^2 Cl O$

Bichlorinated oxide of methyl,	-	-	$C^2 H Cl^2 O$
Perchlorinated oxide of methyl,	-	-	$C^2 Cl^2 O$

5687. Chlorine is absorbed with great avidity by hydrated oxide of methyl, a heavy oil being generated, which has not been well examined.

5688. The reaction of chlorine with chloride of methyl, is the source of a series of compounds, in which, generally, the proportion of chlorine increases as the reaction is prolonged.

Chloride of methyl,	-	-	-	$C^2 H^2 Cl$
Monochlorinated chloride of methyl,	-	-	-	$C^2 H^2 Cl$
Bichlorinated	do.	(chloroform),	-	$C^2 H Cl^2$
Perchlorinated	do.	-	-	$C^2 Cl^2$

5689. The monochlorinated chloride of methyl has an odour which is very sharp, but is, in other respects, similar to the oil of olefiant gas. Distilled with an alcoholic solution of potash, a trifling precipitate of chlorided potassium is formed, and it comes over unchanged.

5690. The perchloride of carbon,  $C^2 Cl^4$ , which is named, above, perchlorinated chloride of methyl, is not altered by a solution of sulphhydrate of potassium. It is decomposed by heat, yielding different chlorides of carbon according to the temperature.

5691. At a low red heat, this chloride,  $C^2 Cl^4$ , appears to be converted into another chloride of carbon,  $C^2 Cl^3$ , supposing the combining measure of the latter to be four volumes, its density being 4082. This new chloride of carbon must therefore be isomeric with Faraday's sesquichloride,  $C^2 Cl^3$ , but of only half the density. When decomposed at a higher temperature, it gives small silky crystals, constituting the chloride of carbon of Julia,  $C^2 Cl$ . Lastly, at a bright red heat, the liquid chloride of carbon,  $C^2 Cl^2$ , is the product.

5692. Chlorine acts readily upon the sulphide of methyl, and upon the compounds of the oxide of methyl with acids, constituting the compound methylic ethers. A benzoate and acetate of an oxychloride of formyl have been produced, having the following formulæ:—



From a mixture of iodine, nitric acid, and wood spirit, left to itself for a long time, yellow crystals are deposited. Bromine, under the same circumstances, yields a heavy oily liquid.

### Of Formyl Ethers.

5693. Hydrated oxide of methyl, when brought into contact with platinum black and atmospheric air, is converted into pure formic acid, by the substitution of two atoms of oxygen for two of hydrogen. The change effected is, therefore, perfectly similar to that by which alcohol is, by the same agent converted into acetic acid. Oxide of methyl, formula  $C^2 H^2 O + HO$  and  $4O$ , is equivalent to formic acid,  $C^2 HO^3 + 3HO$ . Hence the inference, that formic acid contains a radical formyl,  $C^2 H$ , to which it has the same relation as acetic acid has to acetyl: acetic acid,  $C^2 H^2 + O^2$ ; formic acid,  $C^2 H + O^2$  (4019).

5694. Formyl is the hypothetical radical of the following compounds:—

Hydrated oxide of formyl contained in methylal,	$C^2 HO + HO$
Anhydrous formic acid,	$C^2 HO^2$

<i>Hydrated formic acid,</i>	.	.	.	.	.	$C^2 H O^2 + HO$
<i>Perchloride of formyl (chloroform),</i>	.	.	.	.	.	$C^2 H Cl^3$
<i>Perbromide of formyl,</i>	.	.	.	.	.	$C^2 H Br^3$
<i>Periodide of formyl,</i>	.	.	.	.	.	$C^2 H I^3$

*Of Methylal,  $C^2 H^2 O^2$ , a Compound of Hydrated Oxide of Formyl, with Oxide of Methyl.*

5695. By distilling two parts of wood spirit with two parts of peroxide of manganese, and three parts of sulphuric acid, diluted with three parts of water, Dr. Kane obtained a substance mixed with several other bodies, which he named formomethylal. It was considered a tribasic formiated oxide of methyl, but was afterwards shown by Malaguti to be a mixture of formiated oxide of methyl and a particular substance which he named methylal. To purify the methylal from the formiated oxide of methyl, the latter must be decomposed entirely by hydrate of potash.

5696. *Methylal* is an ethereal, colourless liquid, of a very agreeable aromatic odour; which is miscible with three parts of water, and may be separated from that liquid by chloride of calcium, or hydrate of potash. It is very inflammable, and burns with a white flame. The density of methylal is 0.8551; its boiling point  $107^{\circ}.6$ ; its combining measure contains four volumes. Methylal may be represented as a compound of one atom of hydrated oxide of formyl with two atoms of oxide of methyl  $= C^2 HO, HO + 2C^2 H^2 O$ . Regnault has explained its formation, by supposing that three atoms of oxide of methyl, formed by the action of sulphuric acid upon hydrated oxide of methyl, group together so as to form a single molecule  $= C^2 H^2 O^2$ . This molecule, by exposure to peroxide of manganese, loses one atom of hydrogen, gaining one of oxygen, so that the compound  $C^2 H^2 O^2$  results. The formation of acetal, which corresponds with methylal in the acetyl series, is explained by Regnault in the same manner.

5697. *Artificial Oil of Ants,  $C^2 H^2 O^2$*  (Stenhouse).—This name was applied, by Dobereiner, to an oil generated during the preparation of formic acid. It was obtained by Dr. Stenhouse in larger quantity than it is produced during the ordinary process, by distilling a mixture of equal weights of oat-meal, or saw-dust, and sulphuric acid diluted with its own bulk of water. In the process for formic acid, the peroxide of manganese cannot be omitted without greatly reducing the product; but in the process in question it should be left out. When oil of ants is purified, the taste and smell are very pungent and aromatic, resembling that of oil of cassia. It burns very readily with a bright yellow flame. Its density is 1.1006 at  $80^{\circ}.6$ ; its boiling point  $334^{\circ}.4$ . It is soluble in water, but more so in alcohol and ether. It is decomposed by potassium with effervescence; but neither the aqueous nor the alcoholic solution of potash is affected by it.

*Compounds of Formyl with Chlorine, Bromine, Iodine, and Sulphur.*

5698. *Protochloride of Formyl,  $C^2 H Cl$* .—One of the substances which Regnault obtained by the reaction of chlorine with chloride of acetyl, namely,  $C^2 H^2 Cl^2$ , is considered by Liebig as the protochloride of formyl, its atomic weight being divided by two.

5699. *Bichloride of Formyl,  $C^2 H Cl^2$* .—According to Liebig, of one of the combinations, generated by the reaction of chlorine with the chloride of methyl, the formula is  $C^2 H^2 Cl^4$ . This being divided by two, gives that of the bichloride, as above stated.

**5700. Perchloride of Formyl, Chloroform,  $C^2 H Cl^3$ .**—This compound may be made, by exposing a mixture of chloride of methyl,  $C^2 H^3 Cl$ , and chlorine to the direct rays of the sun; by distilling chloral with baryne water, or milk of lime, but more conveniently by distilling a dilute solution of hypochlorite of lime, or bleaching salt, with acetone, alcohol, or wood spirit. For this purpose, one part of slaked lime is suspended in twenty-four parts of water, and impregnated with chlorine till the greater part of the lime is dissolved. The lime must be in sufficient excess, however, to render the liquid slightly alkaline. When the solution of hypochlorite thus made has become clear,  $\frac{1}{3}$  of its volume of alcohol should be added. The aggregate, having been allowed to rest for twenty-four hours, is to be subjected to the distillatory process, at a gentle heat, by means of a capacious retort. The product, consisting of perchloride of formyl, mixed with alcohol, being agitated with water, the perchloride separates as a dense liquid, and may be obtained perfectly pure by digesting it upon chloride of calcium, and rectification with concentrated sulphuric acid.

**5701. Perchloride of formyl** is a colourless, oily liquid, of an agreeable ethereal odour, and sweetish taste; its density is 1.480 at  $64^\circ.4$ ; its boiling point,  $141^\circ.44$ . It is difficult to inflame, but burns in the flame of a lamp, imparting a green colour. An alcoholic solution of potash converts it into formiate of potash, and chloride of potassium, on which the name chloroform is founded,  $2 Po Cl^3$  and  $4 Po O = Po Po O^2$  and  $3 Po Cl$ . The density of its vapour is, by experiment, 4200; by calculation, 4116; its combining measure is 4 volumes. Chloroform may be distilled from sulphuric acid, potassium, or potash, without being sensibly altered. Exposed with chlorine to the direct rays of the sun, it is decomposed, and converted into chlorohydric acid, and a particular chloride of carbon,  $C^2 Cl^2$ , which boils at  $172^\circ.4$ , and of which the density of the vapour is 5300, and combining measure four volumes. This chloride results from the substitution of chlorine for the whole of the hydrogen and oxygen in formic acid,  $C^2 Cl + O^2$ ; while the well known sesquichloride of carbon,  $C^4 Cl^3 + Cl^2$ , is similarly derived from acetic acid.

**5702.** When the above described chloride of carbon is made to pass in vapour through a porcelain tube, at a low red heat, it is resolved into two new chlorides of carbon, of one of which the composition is  $C Cl$ , while of the other the composition is  $C Cl^2$ , according to Regnault.

**5703. Chlorohydrate of the chloride of formyl,  $2 C H Cl H Cl$ ,** is one of the products of the reaction of chlorine, with the chlorohydrate of the chloride of acetyl.

**5704. Perbromide of formyl, bromoform,  $C^2 H$ ,** is prepared like the perchloride, and very analogous to it in properties. Its density is 2.10. It is less volatile than the perchloride, and more easily decomposed by alkalis.

**5705. Periodide of formyl, iodoform,  $C^2 H I^3$ ,** is a yellow, volatile substance discovered by Serullas, which is often described as an iodide of carbon. To obtain it, an alcoholic solution of potash is added to a solution of iodine in alcohol till the last is decolorized, carefully avoiding any excess of the alkali. The alcohol being allowed to escape by gentle evaporation, the iodide of formyl is deposited in crystals, which are purified from iodide of potassium by washing with pure water. This compound results from the reaction of one atom of alcohol, with six atoms of potash and eight atoms of iodine, by which one atom of periodide of formyl, one atom of formiate of potash, five atoms of iodide of potassium, and four atoms of water, are formed.

1 atom of alcohol,	-	-	-	-	C <sup>s</sup>	$\left\{ \begin{array}{l} \text{H} \text{ O} \\ \text{H}^s \text{ O} \end{array} \right\}$			
8 atoms of iodine,	-	-	-	-			I <sup>s</sup>		
6 atoms of potash,	-	-	-	-			O <sup>s</sup>	Po <sup>s</sup>	
					C <sup>s</sup>	H <sup>s</sup> O <sup>s</sup>	I <sup>s</sup>	Po <sup>s</sup>	
1 atom of periodide of formyl,	-	-	-	-	C <sup>s</sup> H		I <sup>s</sup>		
1 atom of formiate of potash,	-	-	-	-	C <sup>s</sup> H	O <sup>s</sup>	Po		
5 atoms of iodide of potassium,	-	-	-	-			I <sup>s</sup> Po <sup>s</sup>		
4 atoms of water,	-	-	-	-		H <sup>s</sup> O <sup>s</sup>			
						C <sup>s</sup> H <sup>s</sup> O <sup>s</sup>	I <sup>s</sup> Po <sup>s</sup>		

5706. Iodoform crystallizes in brilliant yellow plates: has a characteristic odour suggesting that of saffron; is insoluble in water, but very soluble in alcohol, ether, and wood spirit. It sublimes at 212°, and at 248°, is solved into carbon, iodine, and hydriodic acid. When distilled with chloride of phosphorus, or with corrosive sublimate, it yields a peculiar liquid, of a deep red colour, and a density of 1.96, which contains chlorine, iodine, and formyl.

5707. *Sulphide of formyl*, C<sup>s</sup> H<sup>s</sup> S<sup>s</sup> (Bouchardat), is a liquid obtained by distilling one part of iodide of formyl, with three parts of sulphide of mercury. By reaction with hydrate of potash it may be converted into sulphide of potassium and formiate of potash.

### Of Xylite, or Lignone.

5708. Having received from Dr. Ure a bottle of a liquid, which I understood to be pure wood spirit, I subjected it to the usual test of saturating it with chloride of calcium, with which wood spirit reacts eagerly, generating at as already mentioned. I found, however, that a colourless liquid separated, and formed a supernatant stratum, in which the chloride above named did not appear to be soluble.

5709. When this liquid, and the solution of the chloride in wood spirit, were subjected to the distillatory process, by means of a boiling water bath, only the former came over, the wood spirit being retained by the chloride.

5710. It seems from the account given by Graham, 836, that the liquid which was distilled, has been examined by Wiedman and Schweiger, and ascribed under the names at the head of this section. The formula assigned to it is C<sup>s</sup> H<sup>s</sup> O<sup>s</sup>; which, as the admission of half atoms is inconsistent with the grounds on which the atomic theory is built, should be amended.

5711. The boiling point of xylite is about 142°, its density 0.816. The density of its vapour to that of atmospheric air as 2177, by experiment, and 2159 by calculation. Pure xylite has an agreeable, sharp, empyreumatic taste. It is soluble in water, and burns with a white flame.

5712. *Mesiten*, C<sup>s</sup> H<sup>s</sup> O<sup>s</sup>, agreeably to the same authority, is a liquid obtained by distilling equal parts of xylite and sulphuric acid. Chloride of calcium is utterly insoluble in mesiten, of which the boiling point is 145°, and the density 0.808.

5713. *Mesite* is the name given to a liquid which is a concrete product of the destructive distillation of wood, which gives birth to wood spirit and

to xylit. Being less volatile than the last mentioned product, it comes over later, and hence it may be isolated. It is formed also by the reaction of xylite with potash and potassium.

5714. *Xylite Naphtha*,  $C^8 H^6 O_{\frac{1}{2}}$ , results from the reaction of xylite of potash with mesite. It is in its properties ethereal; being colourless, very liquid, and having the odour of peppermint. It is but slightly soluble in water, but very soluble in alcohol, in wood spirit, xylit or ether. It boils at  $230^\circ$ , and burns with white smoky flame.

5715. *Xylite oil* is produced from xylit naphtha, by a renewed reaction with hydrate of potash. This oil has ethereal properties.

5716. *Methal*,  $C^6 H^6$ , is a liquid generated by the reaction between sulphuric acid and xylit. Pyroxanthin, by the distillation of crude wood spirit from slaked lime. These substances are more of the nature of an essential oil, or camphor, than of that of an ether.

#### *Of the Ethereal Compounds of Mesityl, or Mesitylene.*

5717. The origin and characteristic properties of mesityl were stated in the general account of it, as one of the compound radicals among which it stands distinguished as being one of the few which are capable of isolation. As respects its properties, it may be considered as an ether, per se.

5718. *Of the Chloride of Mesityl*,  $C^6 H^3 Cl$ .—I give precedence to this compound over the oxide, contrary to the course pursued in the other cases; as it is only by means of the former that the latter has been obtained. To procure the chloride in question, two parts of perchloride of phosphorus are mixed gradually with one of acetone in a refrigerated vessel. On the addition of water to the resulting mass, an oily liquid separates, which is sufficiently heavy to sink in water, and which heat resolves into chlorohydric acid and mesityl. This oily liquid is the chloride of the last mentioned radical.

5719. *The Oxide of Mesityl*,  $C^6 H^3 O$ , is obtained by the reaction of the alcoholic solution of the chloride, above described, with caustic potash in excess; followed by the addition of a large quantity of water, an oily liquid separates, which, being desiccated by contact with chloride of calcium, is afterwards distilled. Thus purified, it is a colourless liquid, having the odour of peppermint. It boils at  $248^\circ$ , is inflammable, and burns with a brilliant flame, attended with much smoke.

5720. *An impure Iodide of Mesityl* has been obtained by subjecting a mixture of acetone, phosphorus, and iodine, to the distillatory process.

5721. *Chloride of Pteylele*.—When mesityl is impregnated with chlorine, a sort of sub-radical is generated,  $C^6 H^3$ , having a relation to mesityl,  $C^6 H^3$ , analogous to that which acetyl (3093),  $C^4 H^3$ , has to ethyl,  $C^2 H^3$ . With the sub-radical thus generated, which was named by its discoverer, Kane, pteylele, the chlorine combines, forming a chloride.

5722. *Of the Nitrated Oxide of Pteylele*,  $C^6 H^3 Cl$ .—When two parts of acetone, and one part of fuming nitric acid, are mingled, a violent reaction ensues. After the resulting aggregate has become cool, the addition of water causes the separation of a mixture resembling a yellow oil, which consists of two liquids. The more fluid of these has received the name of nitrite of the oxide of pteylele. It is heavier than water, and is decomposed thereby. Paper imbued with it burns like prepared tinder. It is capable of bearing the heat of  $212^\circ$  without decomposition, but at a higher temperature it explodes violently; hence it cannot be distilled.

5723. *Mesitic Aldehyde*,  $C^4 H^6 O + HO$ , or the *Hydrated Oxide of*



**Amyle.**—Of the oily mixture, above described as resulting from the reaction of fuming nitric acid with acetone, mesitic aldehyde forms the more acid portion. It may also be produced by subjecting a mixture of mesityl and nitric acid to ebullition as long as any reaction takes place. From the formula of this, above given, it is seen that it resembles aldehyde in being hydrated oxide of a sub-radical, obtained from another radical by dehydrogenation.

**5724.** Mesitic aldehyde is a heavy, viscid, reddish-yellow liquid, with a rectish taste and penetrating odour.

### *Of Amyl Ethers.*

**5725.** It must appear from the account given of the hypothetical compound radical, amyl (4023), that, in certain compounds it has been inferred to play a part analogous to that which ethyl, methyl, and other bodies of like kind play in certain other compounds; and that, especially, it has been inferred that the oxide of this radical exists in the oil of potato spirit, in union with water. This oil being, therefore, a hydrated oxide of amyl, plays in the compounds of amyl, a part like that which alcohol performs in the ethyl series, or wood spirit in the methyl series. Yet as the oxide of amyl has not been isolated, we have no amylic congener of ether, of which the preparation and properties, in an isolated state, are to be described. Hence, the first object to be presented to the attention of the student is the hydrated oxide.

### *Of the Hydrated Oxide of Amyl, or Oil of Potato Spirit, or Amylic Alcohol, $C^{10}H^{11}O + HO$ .*

**5726.** The congener of alcohol, to which the preceding name has been given, is generated during the vinous fermentation of an infusion of potatoes; and comes over towards the close of the distillation, by which potato spirit is separated from the rest of the products or residue of that process, rendering the water, which simultaneously condenses, milky. Being insoluble in this liquid, it subsides after some time, together with a portion of moisture and alcohol. From the latter of these impurities, it is separated by agitation with water, and from water by chloride of calcium and redistillation. To bring over the pure hydrated oxide of amyl, a temperature of  $270^{\circ}$  is required.

**5727.** Potato spirit is a colourless liquid, oily in appearance, with a strong smell, which at first is pleasant, but becomes afterwards extremely nauseous. The inhalation

of the vapour causes asthmatic pains, cough, and even vomiting. Its taste is very acrid. It burns with a bluish-white flame; boils at  $270^{\circ}$ ; has a specific gravity of 0.8124 at  $60^{\circ}$ . The density of the vapour is  $= 3.147$ , representing four volumes. At  $4^{\circ}$  it solidifies, forming crystalline plates. It produces a stain on paper, which disappears after a short time; dissolves sparingly in water, to which it communicates its odour; and is miscible in all proportions with alcohol, ether, fixed and volatile oils, and strong acetic acid; dissolves sulphur, phosphorus and iodine, without being altered by them; and may also be mixed with a solution of caustic potash, or soda, without change; but when heated with dry potash, hydrogen is disengaged, and valerianate of potash is formed (Dumas, Stas). It absorbs a large quantity of chlorohydric acid gas, with evolution of heat. When mixed with sulphuric acid, a violet colour appears, and the bisulphate of oxide of amyl is produced. When distilled with dry phosphoric acid, a carbohydrogen is obtained, to which Cahours has given the name of amylene. Amylic alcohol combines with the bichloride of tin, forming a crystalline compound, which in the air, and more rapidly when in contact with water, is slowly resolved into its component parts, bichloride of tin, and hydrated oxide of amyl. See valerianic acid (5283).

5728. *Acetate of Oxide of Amyl, Amylo Acetic Ether*,  $C^a H^{10} O$ ,  $C^a H^a O^a = Ayl O$ ,  $Ac O^a$ .—It is easily obtained by distilling a mixture of two parts of acetate of potash, one of hydrated oxide of amyl, and one of oil of vitriol. The product, after being dried by means of chloride of calcium, and rectified along with oxide of lead, yields the acetate in a state of purity. It is a colourless liquid, having an ethereal, aromatic odour, and insoluble in water. It boils at  $248^{\circ}$ .

#### *Of the Bromide and Iodide of Amyl.*

5729. By distilling eight parts of bromine with fifteen parts of amylic alcohol, and one part of phosphorus, a *bromide of amyl*, having ethereal properties, has been obtained; and likewise an *iodide*, by the same process, substituting iodine for bromine. The iodide is described as an ethereal liquid.

5730. *Of Glyceryl and Cetyl*, there are no ethereal compounds. Accordingly, I here terminate the chapter on ethers.

\* A congener of sulphovinic acid (5297).

## OF ANIMAL SUBSTANCES.

---

**5731.** Respecting the substances which come under the preceding definition, I had prepared selections from the former edition of my Compendium, and from all the other more recent sources of information within my reach, when the concluding part of the work on Organic Chemistry, by Liebig and Gregory, fell into my hands. Finding it to be insufficiently condensed, I have concluded to substitute a portion of that work for the matter which I had prepared. My only motive for publishing a text book, has been my inability to find any work comprising descriptions of my apparatus and peculiar experimental illustrations, and having the requisite arrangement and condensation. But as the portion of the work by Liebig and Gregory, to which I have alluded, is deficient neither in arrangement nor in brevity, I deem it judicious to embody it in this Compendium.

**5732.** As certain facts and hypotheses adduced or sanctioned by the philosopher of Giessen and his disciples, constitute the organic chemistry now in vogue, and have an important bearing on physiology, it seems expedient, so far as practicable, to allow them to be studied in that authentic form which they have been made to assume by Gregory, the associate editor of Liebig. Unfortunately, the organic chemistry of Liebig, as translated by Gregory, is in general too voluminous and abstruse, to serve as a chemical text book for a medical class.

**5733.** I shall change some names in order to produce an accordance with the nomenclature adopted in this work, and to correct an inconsistency in using the noun "*nitrogen*," and yet employing the adjective "*azotized*." Evidently either *azot* and *azotized*, or *nitrogen* and *nitrogenized*, are required by consistency.\*

\* The reader will not be misled by some slight differences in orthography, as in *fibrin* and *fibrine*, *legumen* and *legumine*.

*Indifferent Nitrogenized Substances common to the Vegetable and Animal Kingdoms—Proteine and its Modifications.*

5734. "Under this head we have to consider a few very important compounds, which are formed in the vegetable kingdom, and are also found to constitute a large proportion of the animal body. These are *Albumen*, *Fibrine*, and *Caseine*. Till very recently, it was believed that vegetable albumen and fibrine differed from animal albumen, fibrine, and caseine; but the recent researches of Mulder have shown this opinion to be erroneous, and Liebig has demonstrated that caseine exists in vegetables with all the characters of that found in milk (5023).

5735. "The most important step recently made in advance in this important investigation is doubtless the discovery, made by Mulder, that albumen, fibrine, and caseine, are all modifications of one compound, to which he has given the name of *Proteine* (from *πρωτος*, I take the first place), as being the original matter from which all these varieties are derived.

5736. "Proteine is composed of carbon, hydrogen, nitrogen, and oxygen; and Mulder has shown, that two analyses of proteine do not differ more than analyses of fibrine, albumen, or caseine do, either from one another, or from that of proteine, as far as regards these elements. He has further shown, that all of these bodies, whether they contain proteine ready formed or not, readily yield it when acted on by alkalis. While proteine, however, contains no inorganic matter, albumen, fibrine, and caseine each contain small but essential quantities of mineral substances, such as sulphur, phosphorus, potash, soda, common salt, and phosphate of lime. Further, it has been established by the still more recent researches of the school of Giessen, that animal and vegetable albumen, animal and vegetable fibrine, and animal and vegetable caseine, are respectively identical in every particular. We may therefore assume that there is but one albumen, one fibrine, and one caseine; and it is convenient to consider them all as compounds of proteine with small proportions of inorganic matter (5023).

5737. "*Proteine*.—When animal or vegetable albumen, fibrine, or caseine, are dissolved in a moderately strong solution of caustic potash, and the solution heated for some time to  $120^{\circ}$ , the addition of acetic acid causes a gelatinous precipitate, which has the same composition and properties from whichever of these compounds it has been prepared. When well washed and dried, this is *proteine*.

5738. "It forms a yellowish brittle mass, insoluble in water and alcohol. Mulder has analyzed proteine from animal and vegetable albumen, from fibrine and from cheese, or caseine; and Scherer has analyzed proteine from animal albumen and fibrine, from the crystalline lens, from hair, and from horn. The results from all these analyses agree best with the formula  $C^{48}H^{38}N^6O^{14}$  (Liebig); Mulder first gave the formula  $C^{40}H^{31}N^5O^{12}$ . The symbol of proteine is *Pr*.

5739. "Proteine combines with both acids and bases: with diluted sulphuric acid it forms sulphoproteic acid,  $Pr + SO^2$ ; with diluted chlorohydric acid, another acid,  $Pr + 2HCl$ . When chlorine is passed through a solution containing proteine, white flocks are deposited, which Mulder calls chloroproteic acid,  $Pr + ClO^2$ . (Mulder.)

5740. "When proteine, or any of its modifications, is digested in nitric acid, a yellow compound is formed, along with oxalic acid and ammonia. The yellow compound is called xanthoproteic acid, and its formula is  $C^{44}$

$\text{N}^{\circ} \text{O}^{\circ}, 2\text{HO}$ . It seems to combine both with acids and bases. Its salts with bases dissolve with a red colour. (Mulder.)

741. "When boiled with an excess of caustic potash, proteine, albumen, &c. are decomposed, yielding, besides ammonia and carbonic and formic acids, three azotized products, protide, erythroprotide, and leucine. Erythroprotide is a reddish-brown amorphous mass; and its formula, in the pound it forms with oxide of lead, is said to be  $\text{C}^{12} \text{H}^8 \text{NO}^5$ . Protide is yellowish, soluble, uncrystallizable substance, and its formula is  $\text{C}^{12} \text{H}^8$ . Leucine crystallizes in shining scales, which sublime unaltered at  $212^{\circ}$ . Its formula is  $\text{C}^{12} \text{H}^{12} \text{NO}^4$ . With one atom of hydrated nitric acid it yields nitroleucic acid, which forms crystallizable salts. Leucine can also be formed by the action of sulphuric acid on proteine or its compounds. (Mulder.)

742. "According to Mulder, proteine combines with the oxides of lead and silver in the proportion of ten atoms to one of the base: and the same amount of proteine is contained in albumen and fibrine; the former being  $\text{C}^{10} + \text{S}^2 + \text{P}_2$ , the latter  $10\text{Pr} + \text{S}^4 + \text{P}_4$ .

743. "According to Liebig, (Animal Chemistry, p. 106,) proteine is produced by vegetables alone, and cannot be formed by animals; although no animal organism possesses the power of converting one modification of azote into another, fibrine into albumen, or *vice versa*, or both into casein, &c. In this point of view the vegetable forms of proteine, vegetable albumen, fibrine, and caseine, become signally important, as the only sources of proteine for animal life, and consequently of nutrition strictly so called, that is, the growth in mass of the animal body.

744. "Proteine is never found, as such, in nature; but occurs in the form of albumen, fibrine, or caseine, both in vegetables and animals, and in some other forms in the animal body.

### *Modifications of Proteine.*

45. "*Albumen*.—This important substance forms the white of eggs, and occurs in large quantity in the blood. It is also found in other animal fluids, and in most of the animal solids.

46. "It occurs also in many vegetable juices, and in many seeds, such as wheat, almonds, &c. From whatever source it is obtained, its properties are the same.

47. "Albumen is naturally soluble in water, and is found dissolved in the serum of the blood, and in vegetable juices. The white of eggs is quite soluble; and the albumen of wheat flour also dissolves in water, if it have been purified without the application of heat. But when it has once been heated to  $160^{\circ}$ , it becomes insoluble; and, if previously dissolved, a heat of  $160^{\circ}$  causes the dissolved albumen to coagulate, and the coagulum is insoluble in water. Hence albumen is described in two states, the soluble and coagulated.

48. "If white of egg, or serum of blood, be dried up at  $120^{\circ}$ , the residual soluble albumen is in an impure state. It may be purified by being washed with cold ether and alcohol, which remove fat, salts, and other foreign matters.

49. "Dry soluble albumen, when placed in water, first swells up, and forms a glairy fluid. This solution is coagulated by heat, by acids, by alcohol, by creosote, &c. The acids which do not coagulate albumen are acetic acid, phosphoric and pyrophosphoric acids. The coagulated al-

bumen dissolves, with the aid of heat, in strong hydrochloric acid, producing a purple solution. This reaction takes place with all the modifications of proteine, and indicates a great similarity of constitution among them.

5750. "The solution of albumen is also coagulated or precipitated by the acetate of lead and the bichloride of mercury, and by infusion of galls; also by the ferrocyanide of potassium if acetic acid be added. From the insolubility of the precipitate with bichloride of mercury, white of egg, beat up with water, is used as an antidote to that poison. One egg combines with about four grains of corrosive sublimate.

5751. "The precipitates formed by acids are compounds of albumen with the acid employed. They are soluble in pure water, but quite insoluble in diluted acids.

5752. "Coagulated albumen is quite insoluble in water, but is readily dissolved by caustic alkalies, which it even neutralizes. These compounds yield insoluble albuminates with the metallic salts.

5753. "Coagulated albumen, when acted on by hydrochloric acid, yields from one to two per cent. of phosphate of lime; and soluble albumen appears to possess the property of dissolving that salt, a property which enables the blood to convey to the bones their earthy part, and probably also to carry away that which is found in the urine.

5754. "When albumen is analyzed, it yields the same results as proteine, in regard to carbon, hydrogen, nitrogen, and oxygen; but it contains less than one per cent. of sulphur and phosphorus together, which are absent in proteine. According to Mulder, it is  $10\text{Pr} + \text{S}^2 + \text{P}\frac{1}{2}$ ; but we have no means of determining with accuracy such small proportions of sulphur and phosphorus, and it is therefore preferable to represent albumen as proteine with certain small indeterminate proportions of sulphur and phosphorus. When burned, it also leaves ashes, which contain phosphate of lime and alkaline salts.

5755. "To prove the presence of unoxidized sulphur in albumen, dissolve it in potash, then add acetate of lead as long as the precipitate formed is redissolved, and heat the solution to the boiling point. It instantly becomes black by the separation of sulphuret (sulphide) of lead. The same test applies to fibrine and caseine. (Liebig.) It is not known in what state the phosphorus exists in albumen, after phosphate of lime has been separated. The fetid smell of putrefying albumen, indicates distinctly the presence of sulphuretted hydrogen (sulphydric acid) among the products of its putrefaction.

5756. "When the juice of many vegetables, after being separated from the coagulum or deposit which spontaneously forms in it, and which is vegetable fibrine, is heated, a new coagulum is formed, which is vegetable albumen. When nuts, almonds, and similar seeds, are freed from their oil by pressure, the residue is chiefly vegetable albumen in the soluble form. It is, in every respect, identical with the albumen of eggs and of blood.

5757. "Albumen must be considered as the true starting point of all the animal tissues. This appears from the phenomena of incubation, where the tissues are derived from the albumen of the white and of the yolk, which contains albumen also, with the aid only of the air, of the oily matter of the yolk, and of a certain proportion of iron, also found in the yolk. It is clear from this, that albumen may pass into fibrine, caseine, membranes, horn, hair, feathers, &c.

5758. "*Fibrine*.—This modification of proteine occurs, like albumen, in two forms, dissolved and coagulated. The former is found in fresh-drawn blood and in fresh-drawn vegetable juices, from both of which it coagulates spontaneously on standing. In the coagulated state it is found in muscular fibre, and in the gluten of wheat flour and the seeds of the cerealia generally.

5759. "The characters of insoluble or coagulated fibrine closely resemble those of coagulated albumen. With strong acetic acid it forms a jelly, which may be dissolved by boiling water, and is precipitated by ferrocyanide of potassium. It is similarly acted on by other acids; and, like albumen, dissolves in alkalis, which it neutralizes. It gives a purple solution with strong hydrochloric acid.

5760. "When fresh blood is allowed to stand, the fibrine dissolved in it coagulates very soon, and forms the clot, which, however, is coloured by the globules of the blood; but if the blood be stirred with a stick while coagulating, the fibrine adheres to the stick in grey stringy masses, which dry, like albumen, into a horny matter. Like albumen, it contains sulphur and phosphorus, and its ashes contain phosphate of lime. It contains less sulphur, however, than albumen.\*

5761. "As albumen, during incubation, passes into fibrine, so fibrine, in the animal body, passes into albumen; for example, in the case of an animal fed on muscular fibre, whose blood contains the usual proportion of albumen. Nay, Denis has shown that the fibrine of venous blood, by digestion with a solution of nitre, is dissolved, and acquires the characters of albumen, being coagulated by heat and by acids. Scherer has shown that the fibrine of arterial blood does not undergo this change, nor that of the buffy coat, nor even venous fibrine after exposure to the air for some time. Hence he concludes that it is rendered incapable of dissolving by the action of oxygen, and that the fibrine of venous and of arterial blood are thus distinct; the former being soluble, the latter coagulated.

5762. "He found that the above mentioned solution of venous fibrine in nitre, when exposed to the air, deposited an insoluble matter, identical with arterial fibrine. He also observed, that, after being boiled for a short time, venous fibrine became insoluble, and had lost the property, possessed by it when fresh, of absorbing oxygen and giving off carbonic acid.

5763. "The fibrine which spontaneously coagulates from certain vegetable juices, such as those of carrots, turnips, and beet-root, and that contained in the gluten of wheat flour, are identical in properties and composition with animal fibrine.

5764. "Fibrine, both animal and vegetable, is a most important element of nutrition, and yields, in the animal body, albumen, caseine, and the tissues derived from them.

5765. "*Caseine*.—This, the third important modification of proteine, is found in milk, and constitutes that ingredient which is neither coagulated spontaneously, like fibrine; nor by heat, like albumen; but by the action

\* To determine the quantity of fibrine in blood, M. Simon receives it in a flask containing little bits of metal first weighed without the flask, then with this recipient; and after the introduction of the blood, the flask and its contents are weighed together. On agitating the flask, the bits of metal become coated with fibrine. Subsequently they are washed with water, dried, and weighed. By these means, guarding against any deficit, the weight of the fibrine may be deduced. Agreeably to the same authority, menstrual blood contains no fibrine." Berzelius' Report, 1841, page 263.

of acids alone. Cheese, made from skimmed milk and well pressed, is nearly pure caseine. A substance quite identical is found abundantly in the seeds of leguminous plants, and was formerly called *Legumine*. Liebig has recently shown that legumine is nothing but caseine; and, from whatever source, it is found to be a compound of proteine. Thus its analysis gives the same results as those of fibrine and albumen for the four organic elements; and it differs from these bodies in containing no free phosphorus. Its ashes are very rich in phosphate of lime and in potash; and in this point also animal and vegetable caseine agree.

5766. "Coagulated caseine is generally a compound of caseine with the acid employed to coagulate it. When milk, on standing long, coagulates, it is found to contain free lactic acid, some of which by combining with the caseine has caused the precipitate. When sulphuric acid is used, the coagulum is sulphate of caseine; which, when the acid is removed by carbonate of lead, yields pure caseine.

5767. "When dry, caseine thus prepared is like gum. It is not readily dissolved by water, and never forms a clear solution. It is precipitated by acetic acid, but in other respects resembles a solution of albumen, except that it is not coagulated by heat. When milk is placed in contact with rennet, which is the lining membrane of a calf's stomach, it is coagulated. Liebig has shown, that, unless the membrane be in a state of decomposition, this change does not take place; and it probably depends on the formation, under the fermenting influence of the membrane, of sufficient lactic acid to neutralise the alkali of the milk, and thus coagulate the caseine. When sweet milk or cream is used, the cheese contains much butter besides the caseine.

5768. "When milk is heated in an open vessel, a pellicle is formed, which, if removed, is continually renewed, and is insoluble. It is owing to the action of oxygen, for it does not form in an atmosphere of carbonic acid (Scherer.)

5769. "When peas, beans, or lentils are softened in cold water, then ground with that fluid, and the mass further diluted, and strained through a fine sieve, there passes through a solution of caseine in which starch is suspended. When the starch has settled, the supernatant liquid is a solution of caseine, which is always, like milk, turbid, partly from suspended fat, partly from the gradual action of the air on the dissolved caseine, lactic acid being slowly formed, which causes a gradual separation.

5770. "This solution has all the characters of skimmed milk; it is coagulated by acids, not by heat, and forms a pellicle when heated. It also coagulates after long standing from the formation of lactic acid; and, when the coagulum putrefies, the odour is exactly that of putrid cheese. (Liebig.)

5771. "The ashes of soluble caseine, whether animal or vegetable, are very strongly alkaline; and there is reason to believe that the potash found in the ashes had served, by combining with the caseine, to render it soluble.

5772. "Caseine occurs also in the oily seeds, such as almonds, nuts, &c. along with albumen, and must be considered as a very important element of nutrition.

5773. "Scherer, by acting on the serum of blood with water and a little caustic potash, obtained a neutral solution, which no longer coagulated by heat, but formed a pellicle like milk. As this pellicle appeared identical with that from milk, the experiment seems to prove the conversion of albumen into caseine.

5774. "Mulder considers caseine to be  $10\text{Pr} + \text{S}$ ; but pure caseine is



own, and caseine, as it usually occurs, contains 6.5 per cent. of inorganic matter, chiefly phosphate of lime and potash. There is no doubt, however, that the organic elements of caseine are united in the same proportions as those of proteine, albumen, and fibrine; while, like the two latter, it is a purple solution when heated with strong chlorohydric acid. The milk, also, in the nutrition of young animals proves that caseine is capable of conversion into albumen and fibrine; while the production of an animal fed on albumen or fibrine, or both, shows that these bodies may be reconverted into caseine.

5. "We may exhibit the connection between these substances as follows. Pr represents proteine,  $C^{45}H^{80}N^6O^{14}$ . P and S represent, not elements, but only small indeterminate quantities, of phosphorus and sulphur.

Albumen is	.	Pr+S <sup>2</sup> +P+salts.
Fibrine is	.	Pr+S +P+salts.
Caseine is	.	Pr+S +salts.

6. "We can thus easily understand the formation of any one of them from the other. Albumen, losing its sulphur, becomes fibrine; and fibrine, losing its phosphorus, becomes caseine; but the salts are not exactly the same, nor in the same proportions in all the three cases.

### *The Blood.*

7. "This important fluid, from which all parts of the body are formed, possesses very remarkable properties. In the veins it is dark-coloured, in the arteries bright red. When drawn, it presently forms a red clot, and, as we have seen, partly of fibrine, while the serum contains a quantity of albumen.

8. "The colour of the clot is owing to a compound which has been named *Hæmatosine*, which has many properties in common with albumen; the globules of the blood, in which the colour naturally resides, are not coloured of hæmatosine alone, but contain another albuminous compound, to which the name of *Globuline* has been given. It is probable that neither of these compounds is known in a state of purity.

9. "To obtain them, blood is well stirred to separate the fibrine, and with six volumes of a saturated solution of sulphate of soda, in which the globules are insoluble. They are then boiled with alcohol acidulated with sulphuric acid, which dissolves a sulphate of hæmatosine, and leaves a residue of globuline. The red alcoholic solution is mixed with carbonate of ammonia, which separates the sulphuric acid as sulphate of ammonia, leaving a little globuline. The filtered solution, being evaporated, leaves hæmatosine as a dark brownish red mass.

10. "Hæmatosine thus prepared is insoluble in water, alcohol, and ether, but forms red solutions with alcohol, to which either acids or alkalies are added. Its ashes contain iron, but Liebig and Scherer have shown that the colour does not depend on that metal, which may be removed either from the globules, or from hæmatosine, by strong sulphuric acid, without losing the red colour; and in this experiment the red matter left gives a residue, free from iron. Iron, however, is essential to the blood, and is presently supplied in the food. The ashes of almost all vegetables contain little iron; flesh, of course, does so, as it is mixed with blood; and that of egg is found to contain an oily matter, of which iron is an ingredient.

5781. "*Globuline* forms the principal part of the blood-globules. It has not been obtained in a pure state, but has all the characters, as well as the composition, of dissolved albumen. The compound with sulphuric acid above mentioned, is grey, or white, and was found to contain four atoms of sulphuric acid and one of proteine.

5782. "Besides albumen, the serum of the blood contains fat and saline matters. When heated, the albumen coagulates, and floats in a watery liquid called the *Serosity*. This contains common salt, sulphates, phosphates, and carbonates. The blood probably also contains the ingredients of the secretions and excretions, such as bile and urine; but these are in so small a proportion, that, except in cases of disease, it is hardly possible to detect them. The fatty matter in blood is obtained by drying up the serum and digesting with ether. It consists of the usual animal fats, and is said likewise to contain cholesterine, or the fat of bile.

5783. "The following table gives the results of two careful analyses of blood by Lecanu :

						Human blood.	
Water	-	-	-	-	-	780.145	785.588
Fibrine	-	-	-	-	-	2.100	3.565
Colouring matter (hæmotosine and globuline)	-	-	-	-	-	133.000	119.028
Albumen	-	-	-	-	-	65.090	68.415
Crystalline fat	-	-	-	-	-	2.430	4.300
Oily matter	-	-	-	-	-	1.310	2.279
Extractive matter (soluble in water and alcohol)	-	-	-	-	-	1.790	1.930
Albuminate of soda	-	-	-	-	-	1.965	2.000
Alkaline chlorides, carbonates, phosphates, and sulphates	-	-	-	-	-	8.370	7.304
Carbonates of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron	-	-	-	-	-	2.100	1.414
Loss	-	-	-	-	-	2.400	2.565
						1000.000	1000.000

5784. "It is obvious, that, as the blood is chiefly composed of compounds of proteine, its composition cannot be very different from that of proteine or its modifications. In fact, dried blood, when analyzed, yields the formula  $C^{48}H^{30}N^6O^{15}$ , which is proteine,  $C^{48}H^{30}N^6O^{14} + HO + H^2$ . (Playfair and Boeckmann.) This excess of hydrogen is probably derived from the presence of fat.

5785. "From the blood, that is, from the compounds of proteine in the blood, are derived all the animal tissues. Some of these are compounds of proteine, others have no longer the characters of such compounds; but in all cases they are derived from proteine.

5786. "*Muscular tissue*, or *muscular fibre*, is composed chiefly of fibrine, mixed however in the ordinary state with blood, membranes, nervous matter, and fat. Dried flesh, when analyzed, gave the same formula as dried blood, namely,  $C^{48}H^{30}N^6O^{15}$ . (Playfair and Boeckmann.)

5787. "When flesh is acted on by hot water, there is dissolved a quantity equal to 17 per cent. of its weight. The dissolved matter contains the salts of flesh, and several organic matters probably produced in the operation, the nature of which is very little known. One of these has been described under the name of Osmazome, and is supposed to give to soup and dressed meat their peculiar flavour: but osmazome is certainly not a pure substance, as at present known;\* and the whole subject of the changes

\* In other words, osmazome is not a definite compound to which any formula can be assigned, but probably a mixture of substances not yet distinguished.

produced in food by cooking is understood to be under investigation by Liebig.

5788. "*Gelatinous tissue*.—Under this name are included the organic mass of the bones, that of tendons and ligaments, the cellular tissue, the skin, and the serous membranes. All these substances dissolve by long-continued boiling in water, and the solution on cooling forms a jelly. The coarser forms of gelatine, from hoofs, hides, &c. are called *Glue*; that from skin and finer membranes is known as *Size*; and the purest gelatine, from the air-bladders and other membranes of fish, is called *Isinglass*. Gelatine does not exist as such in the animal tissues, but is formed by the action of boiling water.\*

5789. "*Gelatine* is soluble in water, and the hot concentrated solution forms a jelly on cooling. It is precipitated by tannic acid, forming an insoluble compound, which forms the chief part of leather. Leather is made by steeping softened skins in a strong infusion of oak-bark, catechu, or other astringent vegetables containing tannic acid. Skins are prepared in other ways, yielding different kinds of leather, such as tawed leather, wash-leather, &c.; but the process of tanning depends on the action of tannic acid on the gelatinous tissue.

5790. "*Gelatine*, when acted on by sulphuric acid, yields *gelatine sugar*, or *glycicoll*,  $C^8 H^7 N^3 O^5, 2HO$ . When treated with potash, it is said to yield glycicoll and leucine. Glycicoll unites with oxide of lead, forming a compound,  $C^8 H^7 N^3 O^5, 2PbO$ . (Mulder.) It also combines with nitric acid, forming a compound acid,  $C^8 H^7 N^3 O^5 + 2NO^3 + 4HO$ , which crystallizes, and forms double salts with bases. That with lime is  $CaO, C^8 H^7 N^3 O^5 + 2(CaO, NO^3)$ .

5791. "According to Scherer, the composition of gelatinous tissue is represented by the formula  $C^{48} H^{41} N^7 \frac{1}{2} O^{12}$ , or doubled,  $C^{96} H^{82} N^{14} O^{24}$ ; which latter formula represents 2 atoms proteine +  $3NH^3$ , +  $HO$  +  $O^2$ .

5792. "Although gelatine is thus nearly related to proteine, and is doubtless formed from one or other of its modifications, yet it has none of the characters of a compound of proteine. It does not yield proteine when acted on by potash, and it does not produce a purple colour with hydrochloric acid. It therefore no longer contains proteine.

5793. "This accounts for the fact, that animals, fed exclusively on gelatine, die with the symptoms of starvation. The gelatine, containing no proteine, cannot yield albumen, fibrine, or caseine; and it has already been stated that the animal system, although it can convert one form of proteine into another, cannot form proteine from compounds which do not contain it. Blood therefore cannot be made from gelatine, and the animal soon dies. But when mixed with other food, especially compounds of proteine, gelatine may be useful, and may serve directly to nourish the gelatinous tissues. (Liebig, *Animal Chemistry*, 98, 180.) This would explain the use of gelatine as a part of the food of convalescents, whose debilitated system cannot readily convert albumen, &c. into gelatine for the nutrition of these tissues, and finds it ready-made in the food. The experiments of D'Arceet on the gelatine from bones have proved, that, as part of the diet in hospitals, gelatine produces the best effects, and materially abridges the

\* How happens it then, that, as it exists in the hides or skins of animals, it combines with tannic acid to form a substance (leather), precisely the same in its chemical composition as the precipitate formed by a solution of gelatine with that acid?

period of convalescence. When it is given alone, all animals soon reject it with disgust, and die if confined to gelatinous food.

5794. "*Chondrine*.—This substance forms the tissue of cartilage, occurs in the ribs, trachea, nose, &c. and of the cornea. It is slowly dissolved by boiling with water, and when dry resembles glue. But it differs from gelatine in not being precipitated by tannic acid, and in giving precipitates with acetic acid, alum, green vitriol, and acetate of lead. When in the cartilaginous state, are composed of it. According to Scherer it is composed of  $C^{48}H^{80}N^6O^{30}$ ; that is, of proteine +  $4HO$  + bone-earth.

5795. "*Arterial Membrane*.—The middle coat of the artery, which is a very elastic membrane, leaves, when burned, 1.7 per cent of ash. According to Scherer, it is composed of  $C^{48}H^{80}N^6O^{18}$ ; that is, proteine +  $2HO$ .

5796. "*Horny matter*.—This occurs in two forms, *membranes compact*. The former constitutes the epidermis, and the epithelium, lining membrane of the vessels, of the intestines, and of the pulmonary vessels. The latter forms hair, horn, nails, &c.

5797. "Scherer has analyzed numerous specimens of both kinds of horny matter, and deduces from his results the formula  $C^{48}H^{80}N^6O^{18}$ ; that is, proteine +  $NH^3 + O^2$ .

5798. "Horny matter, when acted on by potash, yields proteine + addition of acetic acid.

5799. "*Feathers* are closely allied to horny matters, but, according to Scherer, contain one atom of oxygen less; the formula of feathers, deduced from his analysis, being  $C^{48}H^{80}N^7O^{16}$ .

5800. "*Pigmentum nigrum oculi*.—This substance, according to Scherer, contains more carbon than any of the preceding; but its formula has not been ascertained.

5801. "It is to be particularly observed, that the formulæ above given for the principal tissues of the body, are only intended to show the relative composition they actually bear to proteine. It is not meant that they are formed in the body by the addition of water, ammonia, or oxygen, to proteine; on the contrary, we are as yet ignorant of the conditions under which they are produced; and in some cases, as, for example, in gelatine, several different views may be taken of their formation.

### *Brain and Nervous Matter.*

5802. "*Nervous matter* is distinct from all other animal tissues, and is produced by the animal system exclusively. In composition it is intermediate between fat and the compounds of proteine, containing nitrogen, but is absent in fats, but in far smaller quantity than proteine does; and on the other hand, much richer in carbon than proteine or its compounds. It appears likewise to contain phosphorus as an essential ingredient.

5803. "From the recent researches of Fremy, brain appears to contain a peculiar acid, analogous to the fatty acids, which he calls *cerebric acid*, and which contains nitrogen and phosphorus; this is mixed with an oily substance, with an oily acid—the *oleophosphoric acid*, with *cerebrine*, and finally with small quantities of oleine and margarine, as well as oleic and margaric acids.

5804. "The two acids peculiar to the brain and nervous matter.

sometimes free, but generally combined with soda or with phosphate of lime.

5805. "*Cerebric acid* is extracted by ether from the brain after it has been exposed to the action of boiling alcohol, which coagulates the albumen. The matter deposited on cooling by the ether is a mixture of cerebric acid, generally combined with soda or bone-earth, oleophosphate of soda, and a little albumen.

5806. "This mixture is acted on by alcohol, acidulated with sulphuric acid, which precipitates sulphates of lime and soda, and albumen. The filtered solution contains cerebric and oleophosphoric acids; cold ether removes the latter, and the former is purified by solution in hot ether and crystallization.

5807. "When pure, it is white, crystalline, and pulverizable. In hot water it swells up like starch, but does not dissolve. It contains phosphorus, but no sulphur if purified from albumen; the phosphorus amounts to barely one per cent.; and it contains 2.3 per cent. of nitrogen. It has the characters of a fatty acid, but its acid properties are feebly marked.

5808. "*Oleophosphoric acid*.—This acid has not yet been obtained quite pure. With the alkalies it forms soaps, and its compound with soda appears to exist in the brain. When it is long boiled with water or alcohol, it is resolved into oleine and phosphoric acid. This change is accelerated by acids, but it takes place also spontaneously at the ordinary temperature, only more slowly; and the presence of animal matter in a state of decomposition seems to cause it to be resolved into oleine and phosphoric acid. Thus, when brain has been allowed to undergo partial putrefaction, it no longer yields oleophosphoric acid, but oleine and phosphoric acid. It contains two per cent. of phosphorus. The oleine of this acid is identical with that of human fat.

5809. "*Cholesterine*.—This fat, as extracted from the brain, in which it occurs in considerable quantity, has the same composition and properties as the fat of biliary calculi. (Couerbe; Frémy.) Frémy has also succeeded in detecting in the liver, traces of the characteristic fat acids of the brain.

5810. "The grey portions of the brain appear to be chiefly albuminous; while the white portions consist of an albuminous tissue similar to the grey, but loaded with the fats above described.

5811. "The softening of the brain in diseases of that organ seems to be the result of putrefaction, and is accompanied by the separation of the oleine from the phosphoric acid. The oleine itself also is decomposed, yielding free oleic acid.

5812. "There can be no doubt that the brain and nervous matter (which is quite similar to brain) are formed in the body from compounds of protamine, either by the loss of some azotized compounds, or by the addition of highly carbonized products, such as fat. But we are ignorant in what part of the body, or by what organs, nervous matter is prepared. This point requires minute investigation. In the mean time, according to Chevreul, the fatty matters, which occur in small quantity in the blood, are similar to those of the brain.

5813. "*Bones*.—The bones of animals are composed of bone-earth and gelatinous tissue. By the action of hydrochloric acid, the earthy matter is dissolved, and the animal tissue is left. It is soft, retains the form of the bone, and, when dried, becomes brittle and semitransparent. When boiled

with water, it yields a solution of gelatine, fatty matter remaining undissolved.

5814. "The earthy matter is formed of a peculiar phosphate of lime,  $6\text{CaO} + 3\text{P}^2\text{O}^5 = \text{HO}, 2\text{CaO}, \text{P}^2\text{O}^5 + 2(3\text{CaO}, \text{P}^2\text{O}^5)$ ; that is, a compound of two forms of tribasic phosphate. It forms rather more than half the weight of the bone, and contains a variable proportion of carbonate of lime. Fluoride of calcium is sometimes, but not always, present in recent bones; in fossil bones, and in human bones from Herculaneum, it is always found.

5815. "Teeth contain the same ingredients as bones, but the proportion of earthy matter is greater, amounting to nearly seventy per cent. The enamel of the teeth contains no animal matter, and fluoride of calcium is found in it.

5816. "In rickets, the proportion of earthy matter is much diminished. Callus and exostosis are said by Valentin to contain more carbonate of lime than sound bone, and carious bone to contain less.

5817. "When bones are heated in the open fire, they leave an earthy skeleton, which is quite white, and has the form of the bone. If bones are heated in close vessels, they give off carbonate of ammonia and tarry products, and leave a black mass, which consists of bone-earth, with about ten per cent. of finely divided charcoal. It is called bone or ivory-black, and is much used to decolorize organic solutions.

#### *Animal Secretions and Excretions.*

5818. "Milk.—This important secretion, destined for the support of the young of the mammalia, is characterized by the caseine it contains. But it also contains certain oily or fatty matters which constitute butter, and which, besides fats analogous to the ordinary animal fats, contain certain volatile acids (5052, 5056), to which the smell and peculiar taste of butter are owing. Milk further contains sugar of milk, or lactine (4070); and, when the caseine has been coagulated by an acid, the whey, besides lactine and salts, contains an albuminous matter, which is coagulated by heat.

5819. "The composition of milk is such, that it is capable of supporting animal life without any other food. Its caseine and albumen serve for the formation of blood, and for the nutrition of the animal tissues, while its sugar and fat support respiration; and it furnishes, besides, all the salts which the body requires.

5820. "The following table exhibits the composition of the milk of woman, of the ass, and of the cow. (Henry and Chevallier.)

			Milk of		
			Woman.	Ass.	Cow.
Cheese or caseine	-	-	1.52	1.82	4.48
Butter	.	.	3.55	0.11	3.13
Sugar of milk	.	.	6.50	6.08	4.77
Salts and mucus	.	.	0.45	0.34	0.60
Water	.	.	87.98	91.65	87.02
			100.00	100.00	100.00

5821. "When the food is highly farinaceous, the proportion of butter is increased; but when the food contains much of the compounds of protein, there is less butter and more caseine present. The more active exercise is taken, the smaller also is the proportion of butter.

5822. "Milk, after it has become sour, undergoes the vinous fermentation (5215).

5823. "*Saliva*.—This fluid, secreted by the salivary glands, is composed of water, with about one per cent. of solid matter, partly saline. It often contains a trace of sulphocyanide of potassium, or at least of a salt which strikes a red colour with persalts of iron; but this might be done by an acetate. The animal matter of saliva has been described under the name of *Salivary matter*. It is soluble in water, and not coagulated by heat.

5824. "Saliva possesses, in an eminent degree, the property of frothing with air, like a solution of soap; and Liebig (*Animal Chemistry*, p. 113) conceives that its use is to introduce in this manner, during mastication, a certain quantity of air into the stomach, the oxygen of which is employed in digestion.\*

\* As I find that Berzelius, Graham, and Kane, give more importance to pepsine than is accorded by Liebig and Gregory, I deem it expedient to subjoin the following abridged account of it, prepared by me recently, from Berzelius' Report, 1840, 1842, and Graham's Elements, 1830.

#### *Pepsine.*

The name of pepsine has been given to a peculiar matter constituting the active principle of the gastric fluid, the discovery of which is due to Mr. Wasmann. Pepsine may be obtained by infusing the mucous membrane of the stomach in acidulated water. The solution thus procured, has the property of dissolving the coagulated white of egg completely in half an hour.

When the membrane, without being cut into pieces, but well washed, is digested in a large quantity of water, at a temperature between 86° and 96°, a variety of substances are extracted as well as pepsine; but if afterwards cold water be substituted for the warm, scarcely any matter besides pepsine is taken up. The extraction may endure with successive portions of water, until symptoms of putrefaction ensue. The solution thus obtained, with the addition of a little chlorohydric acid, has the property of dissolving coagulated albumen speedily. Pepsine, extracted by these means, contains a little albumen, which may be precipitated by ferrocyanide of potassium, or by heating the solution, if not too dilute, to a temperature between 170° and 212° without ebullition. By these means the coagulated albumen is precipitated in flocks, with a little modified caseine.

Pepsine may be precipitated from its solutions by the protosulphate of iron, sulphate of copper, acetate of lead, or protochloride of tin. From the precipitates thus made, it may be separated by exposure, while suspended in water, to sulphydric acid.

In precipitating, pepsine retains a sufficient portion of the acid of the saline precipitant to have a decided reaction with litmus, and is highly endowed with its appropriate solvent powers.

Acetate of pepsine may be procured by decomposing, by sulphydric acid, the precipitate made as above suggested, by acetate of lead, evaporating the residual solution to the consistence of syrup, and subjecting it to alcohol. The acetate separates a white flocks, which, by desiccation, acquire the appearance of a gum, and are readily soluble in water. Of pepsine in this form, one part in 60,000 parts of water, with a minute addition of chlorohydric acid, dissolves indurated albumen within about six or eight hours.

A similar efficacy is ascribed to the chlorohydrate of pepsine, which may be obtained by precipitating the solution by bichloride of mercury, and subjecting the precipitate to the process above described in case of the acetate.

Mr. Wasmann has remarked, that the pepsine obtained from the pig is devoid of the power to coagulate milk, although that of the calf is highly endowed with this power.

Agreeably to some comparative trials of the solvent powers of dilute chlorohydric acid, without pepsine, and one other portion of the same acid containing this principle, it appeared that the one was endowed with all the solvent powers of the gastric fluid in a high degree, at ordinary temperatures, while the other, under like circumstances, displayed them only to an insignificant extent; but when the acid, without pepsine, was aided by boiling heat, its solvent powers were equal to that of the solution of pepsine.

5825. "*Gastric Juice*.—This remarkable fluid seems to contain hardly any principle capable of accounting for its solvent power. In the empty stomach it is neutral, but during digestion it becomes acid, from the separation of free muriatic acid. According to Wasmann and other chemists, it contains a peculiar principle, *Pepsine*, which has the property of dissolving food, and which is obtained by the action of water on the well-washed lining membrane of the stomach of the pig. According to Liebig, however, pepsine, as a distinct compound, does not exist. The solution of the lining membrane, slightly acidulated with chlorohydric acid, certainly dissolves albumen and fibrine, if kept in contact with them out of the body at the ordinary temperature. But none of these effects take place, unless the membrane has been previously exposed to the air, and is in a state of decomposition. Hence Liebig ascribes (Animal Chemistry, 109 seq.) the solvent power of the gastric juice to the gradual decomposition of a matter dissolved from the membrane, aided by the oxygen introduced in the saliva. Albumen, &c. when thus in contact with decomposing or fermenting matter, are rendered soluble by a new arrangement of their particles. The accumulation of free chlorohydric acid, derived, no doubt, from common salt, at last puts a stop to further change. The whole food is now brought into the form of *chyme*, an opaque homogeneous fluid, which afterwards passes, first into *chyle*, and finally into perfect blood. In the chyle, the formation of fibrine has already taken place; for, when drawn, it coagulates spontaneously, like blood.\*

5826. "*Pancreatic Juice*.—The fluid secreted by the pancreas is poured into the duodenum, and mixes with the chyme as the latter leaves the stomach. It contains albumen, and, according to some, caseine, and is acid. Its nature, however, is little understood, and its uses at present are unknown.

#### *Bile and Biliary Calculi.*

5827. "The bile is a yellowish green viscid liquid, secreted by the liver. It has a faint disagreeable smell; and its taste is at first sweet, afterwards bitter and nauseous. Ox bile has been chiefly examined, but that of man and other animals is very similar. The researches of Tiedemann and Gmelin, of Berzelius and Demarcay, have shown that bile may be made to yield a vast number of different compounds, most of which are products of decomposition.

5828. "The bile, according to Demarcay, contains soda in combination with a peculiar acid, *choleic acid*. When bile is boiled with an excess of chlorohydric acid, it yields ammonia, *taurine*, and *choloidic acid*; and, when boiled with caustic potash, it yields carbonic acid, ammonia, and *cholic acid*.

5829. "*Choleic Acid*.—When bile is acted on by alcohol, certain impurities are left undissolved. The purified bile gives with acetate of lead a

\* Chyle resembles blood in resolving itself into a coagulum, and a liquid like serum, which, according to Dr. Prout, consists partly of albumen, but principally of incipient albumen. The coagulum, according to Vauquelin, is imperfect fibrin, but Brande considers it as more allied to caseous matter.

The opinions of Prout and Vauquelin derive support from the consideration that, as chyle is destined to become blood, it may be reasonably expected to contain the principal constituents of that liquid, in a state advancing towards maturity. These inferences respecting chyle, made in the former edition of this Compendium, appear to be sanctioned by those of Liebig expressed in the text.



precipitate of choleate of lead, which, when acted on by sulphuretted hydrogen, yields choleic acid.

5830. "It forms a yellow spongy mass, soluble in water and alcohol, which has an acid reaction and a bitter taste, and is decomposed by heat. It combines with soda, forming a compound which Demarçay considers as a soap, the solution of which in water has the physical characters of bile. But although this be the case, and although the composition of the choleic acid appears to be the same as that of the organic part of bile, yet we cannot consider the bile as choleate of soda; for the latter is decomposed by acetic acid, which has no action on bile.

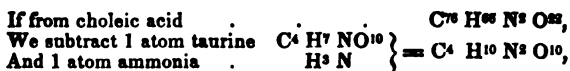
5831. "According to the analyses of Demarçay and Dumas, as calculated by Liebig, the formula of choleic acid is  $C^{76}H^{66}N^2O^{22}$ , and this formula may represent also the organic part of the bile.

5832. "When choleic acid is boiled with chlorohydric acid, it yields ammonia, taurine, and choleidic acid. The latter, being insoluble, is deposited, and the taurine is extracted from the mother liquor by concentrating and adding a large quantity of alcohol, when the taurine slowly crystallizes.

5833. "*Choloidic Acid*.—This acid is solid, fusible, of a yellow colour and bitter taste, insoluble in water, soluble in alcohol. It combines with bases, neutralizing them, and forming salts which are soluble in alcohol. It contains no nitrogen, and its formula is  $C^{73}H^{56}O^{18}$ .

5834. "*Taurine*.—This substance forms white crystalline needles, which are soluble in water, and sparingly soluble in alcohol. Its formula is  $C^4H^7NO^{10}$ .

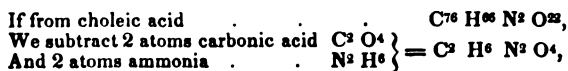
5835. "The production of these substances is easily explained.



There remains 1 atom choloidic acid . . . =  $C^{73}H^{56}O^{12}$

5836. "*Cholic acid*.—This acid is formed, along with carbonic acid and ammonia, when bile or choleic acid is boiled with an excess of caustic potash. It is precipitated by acetic acid, and purified by alcohol from unaltered choleic acid.

5837. "When pure, it forms fine needles, which are permanent in the air; or large tetraedrons, which become opaque on exposure. It is insoluble in water, soluble in alcohol and ether. It forms neutral salts with bases. Its formula is  $C^{74}H^{60}O^{18}$ , and its formation is easily explained.



There remains 1 atom cholic acid . . . =  $C^{74}H^{60}O^{18}$

5838. "Berzelius states that the bile is far from being so simple in its constitution as Demarçay supposes; and by a series of ingenious processes has obtained from the bile a number of different substances, which he has named *Biline*, *Biliverdine*, *Dyslysine*, *Fellinic Acid*, and *Cholinic Acid*, besides taurine and cholic acid, as already described. Biline is essentially the same as Demarçay's choleic acid; and it is probable that most of the others are products of decomposition. But even supposing choleic acid to be composed of two or more different compounds, not isolated by Demar-

say, yet, as Liebig has well remarked, (*Animal Chemistry*, 315) we must not overlook the fact, that it is constant in its composition, and that from this composition we can deduce the principal products of the action of acids and alkalies on bile. It is choleic acid or bile *as a whole*, whether it be a compound or a mixture of several, to which we have to look for the explanation of the changes by which bile may be formed or decomposed. The researches of Berzelius have rendered it probable that choleic acid is not a single compound; but this does not affect its ultimate composition, nor its relation to decomposing agents. It is also clear that bile is very prone to change in almost all circumstances, and yields a great variety of products, most of which have little physiological interest. For these reasons we shall merely refer the reader to the elaborate paper of Berzelius in the foreign journals. The results of Demarçay we have given more in detail; because, as calculated and interpreted by Liebig, they admit of direct application to physiology.

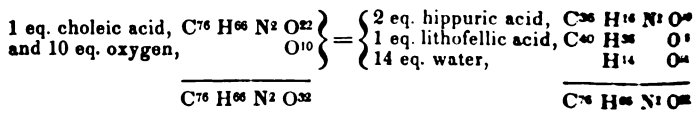
5839. "When dried bile is acted on by alcohol, the pure bile or choleic of soda is dissolved, and the residue is found to contain mucus, salts, and fatty matter. The latter consist of cholesterine and ordinary fat, and possibly contain a portion of the peculiar fats of brain. The dissolved portion, besides true bile, contains a small portion of soaps of margaric and oleic acids with soda.

5840. "The sugar of bile or picromel of Gmelin, so called from its sweet and bitter taste, appears to be choleic acid or biline, altered by the process to which it has been subjected.

5841. "*Biliary Calculi*.—The concretions which form in the gall-bladder, and are often the cause of much suffering, are almost always composed of cholesterine, with more or less colouring matter. Hot alcohol dissolves the cholesterine, and deposits it in shining scales on cooling. These calculi have often a form nearly cubical, and a pearly lustre.

5842. "*Lithofellic Acid*.—This acid has recently been discovered by Goebel in a biliary concretion, and appears to be the chief constituent of the concretions called *bezoar stones*, which occur in herbivorous animals. According to Ettling and Will, its formula is  $C^{40}H^{36}O^8$ . It is soluble in hot alcohol, and forms a crystalline powder on cooling. It is insoluble in water, and forms with alkalies soluble soaps, with oxides of lead and silver insoluble compounds. It is decomposed by heat, and when acted on by nitric acid yields a new acid.

5843. "According to Liebig, who deduced the above formula from the analysis of Ettling and Will, lithofellic acid may be formed, along with hippuric acid, by the oxidation of choleic acid.



5844. "*Excrements*.—The excrements of man contain about one-fourth of their weight of solid matter. The ashes of dry *faeces* amount to 13.50 to 15.00 per cent., and are composed of phosphates and other salts. The excrements also contain nitrogen, and yield ammonia when they putrefy. The value of night-soil as manure depends on the salts and ammonia of the *faeces*, and also in a great measure on the ammoniacal and other salts of

rine. The colour of *feces* is generally said to be owing to bile; but *g* states that there is only a mere trace of bile, if any, to be found in *feces* either of man or animals. The yellow matter of *feces* is insoluble in alcohol, with the exception of a small proportion, and even that has the characters of bile.

45. "*Lymph*.—The lymph of cellular membrane is water, with a trace of albumen and of common salt. The lymph secreted by the serous membranes is much more highly charged, containing seven or eight per cent. of albumen and salts. It coagulates when heated, or by the action of nitric acid. The liquor amnii and the fluid of hydatids is similar; the fluid of dropsy is said to contain urea, and to have cholesterine suspended in it.

46. "*Mucus*.—This is the secretion of the mucus membranes. When dried it leaves six or seven per cent. of yellowish solid matter, of which five parts are mucus, the remainder albumen and salts. Mucus does not dissolve in water, but swells like tragacanth into a viscid mass. It dissolves in caustic potash.

47. "*Pus* is the matter secreted by ulcerated surfaces. When healthy, it is a thick yellowish liquid, formed of opaque globules floating in a clear serum. When mixed with water, the globules fall, forming a yellow insoluble sediment. Pus contains about 14 per cent. of solid matter, and is coagulated by heat and by acids. It contains albuminous matter, fatty matter and salts.

48. "The matter of the globules of pus is similar to that of the globules of blood, or globuline. Pus is distinguished from mucus by the microscope, or by the action of caustic potash, with which pus becomes thick and opaque, while mucus forms a thin solution.

#### *Urine and Urinary Calculi.*

49. "*Urine*.—This important excretion is separated from the arterial blood in the kidneys. It has a pale yellow colour, and a peculiar smell. Its specific gravity varies from 1.012 to 1.030. It has an acid reaction, or is neutral, but never alkaline in a state of health.

50. "On standing, it deposits a slimy mucus-like substance, secreted by the lining surface of the bladder. This mucus acts as a ferment, and causes the urine, after a time, to undergo decomposition; for, when it is filtered by the filter, the urine may be kept unchanged for a much longer time.

51. "When spontaneous decomposition has taken place, the urine is rendered turbid from the presence of carbonate of ammonia, derived from the urea. It contains about seven or eight per cent. of solid matter, the remainder being water.

52. "The characteristic organic principles of urine are urea and uric acid (5359, 5361). The urea\* has been recently declared by Cap and

*Anomalous Cyanate of Ammonia; Urea*.—Discovered by Fourcroy and Vauquelin in urine, by Wöhler as the first organic compound artificially produced. It is a constituent of uric acid, and is contained in the urine in combination with lactic acid (Henry). Urea is also a product of the reaction of cyanogen on water when a small amount of that gas is allowed to undergo spontaneous decomposition (Pelouze and Dechen).

*sp.*—By mixing fresh urine evaporated to the consistence of a syrup at a gentle heat, which should never reach that of ebullition, when still warm, with its own weight of colourless nitric acid of *sp. gr.* = 1.42. If the evaporation has been care-

Henry to be combined with lactic acid; but, in repeating their experiment the editor has always obtained pure urea instead of the lactate. It appears, therefore, that in some individuals it occurs uncombined, it

ried sufficiently far, the whole will form a thick crystalline mass; to insure a small portion of the urine should be tried from time to time. The crystalline consists of a compound of nitric acid and urea, which is sparingly soluble in acid. By the action of the nitric acid on the warm solution, heat is developed, effervescence ensues. This is chiefly owing to the destruction of the color matter, and if no external heat is applied, the urea not only is not decomposed, but forms, from the first, nearly white crystals of nitrate. When cold is employed according to the method formerly recommended, the crystals are very brown and purified with difficulty. It is advisable to separate from the inspissated mass as much as possible of the chlorides it contains, by crystallization, before adding nitric acid (Cap and Henry).

"A solution of the colourless crystals of the nitrate of urea is treated with carbonate of baryta until it is rendered perfectly neutral; on evaporating, a nitrate of baryta, and then of urea, will be obtained. The crystals of the latter, being redissolved in a little cold water, are freed from the last portions of the nitrate of baryta; the solution in alcohol gives crystals of pure urea (Wöhler). Wöhler states that coloured crystals of urea are best decolorized by a little permanganate of potash, which destroys the colouring matter, but has no action on urea. The excess of the salt is removed by alcohol, which converts it into peroxide of manganese.

"Instead of using nitric acid, the concentrated urine may be added to a saturated solution of oxalic acid, when the sparingly soluble oxalate of urea, which, after being deprived of its colour by charcoal, may be decomposed into insoluble oxalate of lime and pure urea, by being digested with pounded chalk (Zellius). It can also be prepared by the decomposition of the cyanate of silver by sal ammoniac, or of the cyanate of oxide of lead by pure or carbonic ammonia."

"*Prop.*—Crystallizes in colourless, transparent, four-sided, somewhat prismatic, of the sp. gr. 1.35, is soluble in its own weight of cold, and in every 10 parts in hot water, in 4.5 parts of cold, and in 2 parts of boiling alcohol: the solution has a cooling bitter taste like nitre; when pure, it is perfectly pure in the air, is not deliquescent, fuses at 250° into a colourless liquid, is decomposed by a higher temperature into ammonia, cyanate of ammonia, and dry solid acid. Alkalies do not cause the separation of ammonia in the cold. On treating several acids without decomposition to crystallizable saline compounds by saturating its solution with nitrate of silver or acetate of lead it is decomposed: the products being, with the first, nitrate of ammonia and crystalline cyanate of silver; with the second, acetate of ammonia and carbonate of lead. With hyponitrous acid it is instantly decomposed into nitrogen and carbonic acid gases, which are in equal volumes; with chlorine it forms hydrochloric acid, nitrogen, and carbonic acid. When fused with the hydrated alkalies, or heated in concentrated nitric acid, it is decomposed together with the constituents of three eq. of water into carbonic acid and ammonia. Urea contains the elements of cyanate of ammonia ( $\text{C}^2\text{NO}$ ); it may also be considered, according to Dumas, as a second compound of carbonic oxide and amide, in which the quantity of the latter is double that of the amide  $\text{C}^2\text{O}^2 + 2\text{NH}^2$ .

"*Nitrate of Urea.*—This compound, when recently precipitated from urea, appears in the form of fine crystalline plates of a brown colour and mother luster; the purer they are, the more they lose this appearance: a solution of urea treated with nitric acid gives a granular white crystalline precipitate, which is soluble in eight parts of cold, but more freely in hot water, from which it crystallizes in broad, scarcely translucent plates; is sparingly soluble in nitric acid, but it may be boiled without decomposition. It is composed of one eq. of nitric acid and one of urea, and one of water (Regnault)."

\* I am surprised the following process is not mentioned:—Impure cyanate of potassium is prepared by roasting the cyanoferrite of potassium. Aqueous solution of cyanate thus obtained, and of sulphate of ammonia, being mingled, the mixture is subjected to boiling alcohol, which takes up the urea only. On cooling, it crystallizes, and may be rendered purer by recrystallization from the mother liquor. Kane, 1164.

as lactate. It is not known precisely in what state of combination the uric acid occurs; but, when it is not deposited spontaneously, it appears on the addition of an acid, and the spontaneous deposition of it is probably owing to the presence of free acid in unusual quantity.

5853. "The proportion of urea has been found by Lecanu to be tolerably uniform in the same individual, but to vary much in different persons. It is larger in adult men than in women, and least of all in old people and very young children. The proportion of uric acid varies in a similar way. The following analysis of urine, by Berzelius, will give a view of the usual composition of human urine:—

Water	-	-	-	-	-	-	933.00
Urea	-	-	-	-	-	-	30.10
Uric acid	-	-	-	-	-	-	1.00
Lactic acid, lactate of ammonia, and animal matter adhering to them	-	-	-	-	-	-	17.14
Mucus of the bladder	-	-	-	-	-	-	0.32
Sulphate of potash	-	-	-	-	-	-	3.71
Sulphate of soda	-	-	-	-	-	-	3.16
Phosphate of soda	-	-	-	-	-	-	2.94
Phosphate of ammonia	-	-	-	-	-	-	1.65
Chloride of sodium	-	-	-	-	-	-	4.45
Hydrochlorate of ammonia	-	-	-	-	-	-	1.50
Earthy matters, with a trace of fluoride of calcium	-	-	-	-	-	-	1.00
Siliceous earth	-	-	-	-	-	-	0.03
							<hr/> 1000.00 <hr/>

5854. "Scharling has recently examined the brown organic matter which gives the colour to inspissated urine, and seems also to be the source of its peculiar odour. He obtained a brown, fusible, resinous mass, having a strong odour of castoreum when dry, and a urinous smell when boiled with water. He calls it *oxide of omichmyle*, (from *ουριχμα*, urine,) and supposes it to contain a radical, omichmyle, the composition of which is still unknown.

5855. "When urine is distilled with an excess of nitric acid, there are formed several products, among which Scharling states that he has observed benzoic acid, and an acid containing chlorine derived from the salts of the urine. This acid appears also to be formed when oxide of omichmyle is distilled with nitromuriatic acid. From his analysis, Scharling deduces the formula  $C^{14}H^4ClO^3 + HO$ , which represents benzoic acid, in which one eq. of hydrogen is replaced by one eq. of chlorine. It is also isomeric with chloride of salicule or chlorosaliculinic acid (5336).

5856. "Along with this acid there is formed a volatile greenish-yellow oil, which Scharling found to contain twice as much chlorine, and the elements of nitric acid. This compound he calls nitro-chloromichmyle. When heated with acids, it is decomposed, and yields another oily matter, chloromichmyle. All these observations require confirmation.

5857. "The urine of herbivora is alkaline, and, when the animals are stall-fed, contains, besides urea, hippuric acid; but when they live in the open air, or are forced to labour, benzoic acid alone is found.

5858. "The urine of the carnivora is acid, and contains phosphates and sulphates of ammonia and soda, as well as uric acid and urea.

5859. "The urine of serpents and of birds is of a soft semisolid consistence, and dries into a mass like chalk. It is almost pure urate of ammonia, but contains a small quantity of phosphates.

5860. "*Urinary Calculi*.—The most abundant calculi are those of *uric acid*. They have generally a fawn colour, are soluble in caustic potash, and precipitated from the solution by acids. They also dissolve in *succinic acid* with the aid of heat; and the solution, when gently evaporated to dryness, leaves a purple stain of murexide. This species of calculus is totally consumed before the blowpipe, leaving a mere trace of ashes.

5861. "*Urate of Ammonia* occasionally forms a calculus, which is distinguished from the former by giving out ammonia when digested with potash.

5862. "*Bone-earth* forms a common calculus, which is earthy, soluble in diluted acids, except acetic acid, insoluble in potash, and indestructible by heat.

5863. "*Ammoniaco-magnesian Phosphate* also occurs pretty frequently. It is the same double salt which forms whenever magnesia, phosphoric acid, and an excess of ammonia, are brought together. It is soluble in acetic acid, and precipitated again by ammonia. It has often a crystalline aspect. When heated, it gives off ammonia, and leaves phosphate of magnesia.

5864. "*Fusible Calculus*.—This very common calculus is a mixture of the two preceding. It is white and chalky, and melts easily before the blowpipe. Acetic acid dissolves part of it, hydrochloric acid the rest.

5865. "*Oxalate of Lime*, or *Mulberry Calculus*, has a dark-coloured rough surface, and is very hard. It is insoluble in acetic acid; but, when heated to redness, it is converted into carbonate of lime, which dissolves in acids with effervescence.

5866. "*Xanthic Oxide* is a rare calculus, first observed by Dr. Marcet. It has a light brown colour, and becomes resinous by friction. It dissolves in caustic potash, and is precipitated from the solution by carbonic acid. It dissolves in nitric acid without effervescence; and, when evaporated, leaves a yellow mass. Its formula is  $C^5 H^8 N^8 O^8$ .

5867. "*Cystic Oxide* is also very rare. Discovered by Wollaston. It is yellowish-white and crystalline, with a waxy lustre. It dissolves in caustic potash, and is deposited from the solution in hexagonal plates on the addition of acetic acid. It also dissolves in ammonia and the mineral acids; with the latter it forms crystalline compounds. When its solution in potash is heated, ammonia is first given off, and afterwards a combustible vapour, with the odour of sulphuret of carbon. Its formula is  $C^8 H^8 N^8 O^4$ .

5868. "Both the preceding species are entirely consumed before the blowpipe.

5869. "Calculi sometimes occur, in which layers of uric acid alternate with layers of phosphate of lime, ammoniaco-magnesian phosphate, and fusible calculus.

### *Changes which occur during the Life, Growth, and Nutrition of Vegetables and Animals.*

5870. "When we consider that the food of vegetables and of animals is either altogether different from their substance, or passes, before being assimilated, into a new form, we cannot hesitate to admit that the nutrition and growth of both classes of organized beings depend on chemical agencies, although these operate under peculiar conditions, and are influenced by the unknown force which we call Vitality, so as to produce re-

sults that cannot be imitated by the chemist in his experiments on dead matter.

5871. "The food of vegetables, as far as their organic structure is concerned, consists entirely of inorganic compounds; and no organized body can serve for the nutrition of vegetables until it has, by the processes of decay or putrefaction, been resolved into certain inorganic substances.

5872. "These are carbonic acid, water, and ammonia, which are well known to be the final products of putrefaction. But, even where these are supplied to vegetables, their growth will not proceed unless certain mineral substances are likewise furnished in small quantity, either by the soil, or in the water used to moisten it. Almost every plant, when burned, leaves ashes, which commonly contain silica, potash, phosphate of lime; often also magnesia, soda, sulphates, and oxide of iron. These mineral bodies appear to be essential to the existence of the vegetable tissues, so that plants will not grow in soils destitute of them, however abundantly supplied with carbonic acid, ammonia, and water.

5873. "In the process of germination, oxygen is absorbed, heat is given out, and in some cases at least an acid, said to be the acetic, is formed, the use of which appears to be to extract from the soil the bases necessary for the future progress of the plant. The starch, or albumen of the seed, becomes soluble, and in the juice undergoes certain changes, by which the woody fibre or lignine, required for the stem and leaves, is produced; but, as soon as leaves and roots are developed, the further nutrition of the plant depends on their power of absorbing from the atmosphere and the soil the matters which constitute the food of the plant.

5874. "According to Liebig (see his *Agricultural Chemistry*), the whole of the carbon is now derived from carbonic acid, which is either absorbed from the atmosphere and rain-water by the leaves, or from the moisture and air in the soil by the roots. Its carbon is retained, and its oxygen given out; this decomposition being effected in the plant at all times when exposed to the action of light, along with a certain temperature.

5875. "The hydrogen and oxygen of vegetables are derived from water; and the reader will here observe, that the great mass of vegetables, consisting of lignine, starch, gum, &c. is actually composed of carbon plus water.

5876. "The nitrogen of vegetables is derived chiefly, if not exclusively, from ammonia, which is supplied to them in rain. Liebig has shown beyond all doubt, that rain-water always contains more or less carbonate of ammonia. If we acidulate pure rain-water with a little sulphuric acid, and evaporate to a small bulk, the addition of lime causes the disengagement of ammonia, easily known by its pungent smell. It is remarkable that the ammonia of rain-water has always a putrid smell, which indicates its origin. In fact, it is derived from the putrefaction of preceding races of animals and vegetables, and must at all times exist in the atmosphere; although its relative quantity is so small, that it is not easily detected until it has been accumulated in rain, which, in passing through the air, dissolves it readily, and conveys it to the earth.

5877. "It is also to be observed, that the soil itself, like all porous bodies, possesses the property of absorbing ammonia, and therefore will attract it from the atmosphere. Alumina, peroxide of iron, and humus, all absorb ammonia powerfully. Gypsum (sulphate of lime) and other sulphates convert the carbonate of ammonia into the more fixed sulphate, which remains

in the soil till absorbed by the roots. This explains in a great measure the use of these ingredients in fertile soils.

5878. "It is only under the influence of light that plants can decompose carbonic acid, fixing its carbon and setting free its oxygen. During the night, on the contrary, they undergo a kind of slow combustion, oxygen being absorbed, and carbonic acid formed. But the balance in this curious alternation is vastly in favour of the process by which oxygen is sent into the atmosphere, for, the whole carbon of a forest, for example, being derived from carbonic acid, an equivalent quantity of oxygen must have been liberated; and this consideration alone enables us to explain the fact, that, notwithstanding the enormous amount of oxygen withdrawn from the atmosphere by the respiration of animals, by combustion, by putrefaction, and by the action of vegetables during the night, in all of which processes the oxygen is converted into carbonic acid of equal volume, the proportion of oxygen in the atmosphere does not diminish, and that of carbonic acid does not increase.

5879. "From these considerations it appears that there must always exist a balance or fixed proportion between the existing amount of animal and that of vegetable life. Where animals abound, and where men carry on the usual operations of civilized life, there, carbonic acid must be largely formed. But this carbonic acid, in yielding its carbon to vegetation, yields also its oxygen to restore the purity of the air, and support again the respiration of men and animals. Again, the decay and putrefaction of both animals and vegetables yield carbonic acid and ammonia, the very substances which form the food of a new race of vegetables; and these again contribute to the nourishment of new animals; so that, in this unceasing round of chemical changes, the death of one generation supplies the means of life to that which is to follow.

5880. "It has long been the prevailing opinion, that the carbon of plants is derived directly from humus or humic acid existing in the soil, which is supposed to be absorbed in the form of a solution in water, or as humate of ammonia; but it must be admitted, as Liebig has shown, that there is no evidence whatever that humus is directly absorbed by plants. Humus, as it exists in the soil, is almost entirely insoluble in water, and, when a soluble form occurs, the solution, however weak, is always of a dark brown colour; whereas the juices of plants, when first absorbed, are colourless. Again, humic acid, as described by chemists, never occurs in soils, but is a product of the action of alkalis on humus, and besides forms solutions as dark-coloured as those of humus. Good fertile soil digested with cold water yields to it no colour; water, filtering through such soil, passes colourless, as may be daily observed; nay, moss-water, which is actually coloured brown by humus, is decolorized by passing through a good fertile soil containing humus; finally, a peaty soil, which contains more humus than any other, is notoriously barren.

5881. "On the other hand, the first vegetables which grew on the earth could not have derived their carbon from humus, which is a product of the decay of vegetables, but could only have obtained it from carbonic acid; and if this source of carbon were then sufficient, there is no reason to look for another. Besides, if we reflect on the extreme luxuriance of vegetation in uninhabited countries, where the soil has never been manured, we cannot fail to perceive that the carbon of that vegetation must have been chiefly derived from the atmosphere; and when, in addition to this, we find that the proportion of humus in all soils bearing vegetation increases rather than



diminishes, in spite of the vast amount of carbon annually accumulated and removed in the crops, we are compelled to adopt the same conclusion.

5882. "This latter consideration shows, that the humus and other organic matters in manures do not act directly in furnishing carbon, and that their use chiefly depends on other ingredients. These, as Liebig has demonstrated, are, first, the ammonia they contain or yield by putrefaction; and, secondly, the mineral bodies, such as potash, phosphate of lime, &c., found in their ashes.

5883. "But, although there is no evidence that humus is directly absorbed by plants, and the phenomena of peat and mossy soils prove, that the soluble forms of humus are unfavourable to vegetation, yet it cannot be doubted that humus or mould, both of the soil and the manures, performs an important function. It slowly and gradually undergoes combustion, yielding a constant and steady supply of carbonic acid in moderate quantity. This is partly absorbed by the roots, and partly rises into the atmosphere to be absorbed by the leaves; but, as the proportion of humus in the soil does not diminish, that which is thus consumed is probably restored to the soil by the secretions, or rather excretions, from the roots.

5884. "Humus also probably acts by absorbing and fixing the ammonia of the atmosphere.

5885. "According to the views above stated, which have been admirably laid down by Liebig in his *Agricultural Chemistry*, the chief use of manures is not to supply plants with carbon, but with ammonia and inorganic matters. Every plant requires certain mineral substances, without which it cannot prosper; and a soil is fertile or barren for any given plant, according as it contains these. Thus, the ashes of wheat-straw contain much silica and potash, while the ashes of the seeds contain phosphate of ammonia and magnesia. Hence, if a soil be deficient in any one of these, it will not yield wheat. On the other hand, a good crop of wheat will exhaust the soil of these substances, and it will not yield a second crop till they have been restored, either by manure or by the gradual action of the weather in disintegrating the subsoil. Hence the benefit derived from fallows and from the rotation of crops.

5886. "When, by an extraordinary supply of any one mineral ingredient, or of ammonia, a large crop has been obtained, it is not to be expected that a repetition of the same individual manure next year will produce the same effect. It must be remembered, that the unusual crop has exhausted the soil probably of all the other mineral ingredients, and that they too must be restored before a second crop can be obtained.

5887. "The salt most essential to the growth of the potato is the double phosphate of ammonia and magnesia; that chiefly required for hay is phosphate of lime; while for almost all plants potash and ammonia are highly beneficial.

5888. "From the principles above mentioned we may deduce a few valuable conclusions in regard to the chemistry of agriculture. First. By examining the ashes of a thriving plant, we discover the mineral ingredients which must exist in a soil to render it fertile for that plant. Secondly. By examining a soil, we can say at once whether it is fertile in regard to any plants, the ashes of which have been examined. Thirdly. When we know the defects of a soil, the deficient matters may be easily obtained and added to it, unmixed with such as are not required. Fourthly. The straw, leaves, &c. of any plant must be the best manure for that plant, since every vegetable extracts from the soil such matters alone as are essential to it.

This important principle has been amply verified by the success attending the use of wheat-straw or its ashes as manure for wheat, and of the clippings of the vines as manure for the vineyard. Where these are used, no other manure is required. Fifthly. In the rotation of crops, those should be made to follow which require different minerals; or a crop which extracts little or no mineral matter, such as peas, should come after one which exhausts the soil of its phosphates and potash.

5889. "Of the chemical manures now so much used, *bone-dust* supplies the phosphates, which have been extracted by successive crops of grass and corn, the whole of the bones of the cattle fed on these crops having been derived from the soil; its gelatine also yields ammonia by putrefaction. *Guano* acts as a source of ammonia, containing much oxalate and urate of ammonia with some phosphates. *Night-soil* and *urine*, especially the latter, are most valuable for the ammonia they yield, as well as for phosphates and potash: but are very much neglected in this country, although their importance is fully appreciated in Belgium and China. *Bran* is a very valuable manure, especially for potatoes, as it contains much of the ammoniac-magnesian phosphate.

5890. "*Nitrate of Soda* probably acts by its alkali, replacing potash, but it is possible that its acid may also yield nitrogen to plants, although we possess at present no evidence of this, and indeed no evidence that plants can derive their nitrogen from any other source than from ammonia.

5891. "Such is a brief sketch of the general laws of vegetation as at present known, in so far as they are connected with chemistry. Of the changes in the juices of vegetables, by which the numerous products of the vegetable kingdom are formed, we know nothing. The juices of plants contain ammonia and sugar, gum or starch; all the elements are therefore present from which the nitrogenized compounds, albumen, fibrine, and caseine, in other words, proteine, may be formed, and it appears that vegetables alone can produce proteine. Thus the final products of vegetation form the food of animals; the modifications of proteine serving for nutrition, properly so called, and the starch, gum, sugar, and oil serving for the support of respiration.

5892. "The life of animals is distinguished chemically from that of vegetables by the circumstance, that in the former oxygen is constantly absorbed and replaced by carbonic acid, while in the latter carbonic acid is absorbed, its carbon retained, and its oxygen given out. Consciousness and the power of locomotion are peculiar to animals.

5893. "In animals two processes are constantly carried on; that of respiration, by which the animal heat is kept up; and that of nutrition, by which the matter consumed in the vital functions and expelled from the body is restored.

5894. "Respiration is essentially a combustion of carbon, which in combining with oxygen is converted into carbonic acid, and at the same time furnishes the animal heat. Liebig calculates that the amount of carbon daily burned in the body of an adult man is about fourteen ounces, and that the heat given out is fully sufficient to keep up the temperature of the body, and to account for the evaporation of all the gaseous matter and water expelled from the lungs.

5895. "This carbon is derived in the first place from the tissues of the body, which undergo a constant waste, but ultimately from the food.

5896. "In the carnivora, whose food is almost entirely composed of compounds of proteine, albumen, &c. one part is devoted to supply the

waste of the tissues, while another portion, or a corresponding amount of previously existing tissue, is decomposed so as to yield the carbon required for respiration. As the tissues can only be decomposed by the exercise of the vital functions, this is the reason why, in the carnivora, an enormous amount of muscular motion is required to furnish the necessary supply of carbon.

5897. "On the other hand, the food of the herbivora contains but little of the compounds of proteine, only sufficient to restore the waste of the tissues; while the carbon required for respiration is supplied by the starch, gum, sugar, oil, &c. which form the great mass of their food, and no such amount of muscular motion is required in them as in the carnivora.

5898. "It is in the form of bile chiefly that the carbon undergoes combustion. Hitherto, the true function of the bile has been disputed; and by most authors that fluid has been considered as an excretion, intended to be expelled from the body in the fæces. But Liebig has shown that only a small fraction of the whole amount of bile can be detected in any shape in the fæces, and that the bile unquestionably is reabsorbed in the intestinal canal, and re-enters the circulation, where it soon disappears; and as the proportion of carbon in the bile is very large, although not sufficient to account for all the carbonic acid given out, there is no reason to doubt that it is gradually consumed by the oxygen of the arterial blood, and converted into carbonic acid and water, which escape by the lungs and skin.

5899. "To return to the subject of the animal heat: the food that is required, and hence the appetite, must be proportional to the amount of carbon required to supply the animal heat. Now, in hot climates, where the external cooling is less, less heat is required, the appetite is much more feeble, and the usual food, consisting of fruits and vegetables, contains a far smaller amount of carbon than in cold climates, where the appetite is keen, and the food highly carbonized, such as flesh, or even blubber. For the same reasons, warm clothing, by diminishing the loss of heat by external cooling, blunts the appetite; and those who remove from a cold to a warm climate always find that their appetite fails. This is a warning from nature to diminish the amount of food taken; and if it were attended to, and the common but absurd practice of stimulating the appetite by ardent liquors and hot spices abandoned, Europeans might enjoy as good health in the East or West Indies as at home. It is obvious that, even in Europe, more food is required in winter than in summer. (Animal Chemistry, 23.)

5900. "In endeavouring to explain the formation of the bile, it is obviously of no moment whether we derive it from the albumen, fibrine, &c. of the food, or those of the tissues, their composition being identical. Liebig, assuming choleic acid to be the chief organic constituent of the bile, and its formula to be  $C^{76}N^3H^{66}O^{22}$ , has shown that the half of this formula, added to that of urate of ammonia,  $C^{10}H^5N^7O^6$ , which gives the sum  $C^{43}N^6H^{33}O^{17}$ , is equal to the formula of blood or flesh,  $C^{44}N^6H^{33}O^{15}$ , with the addition of one atom water and one atom oxygen. (Animal Chemistry, 185, 26.) Again, proteine,  $C^{44}N^6H^{33}O^{14}$ , plus three atoms of water, gives the same sum, excepting one atom of hydrogen, viz.  $C^{44}N^6H^{33}O^{17}$ . In this way we can see how the tissues, acted on by oxygen and water, may yield the ingredients of bile and urine. This is the first attempt which has been made to trace chemically the connection between the food, the blood of the tissues, and the secretions or excretions; and showing, as it does, that these questions are capable of elucidation on chemical principles, it

must be regarded as the most important idea yet suggested in animal chemistry.

5901. "Supposing it to be well-founded, the tissues which are consumed are resolved first into bile and urate of ammonia. The former is secreted from the liver, reabsorbed and burned, as before stated. The latter, in reptants and birds, is expelled unchanged; but in man and quadrupeds, in whom the amount of oxygen inspired is much greater, it is also oxidized, yielding finally carbonic acid, ammonia, and urea.

5902. "Should the supply of oxygen in the human subject be sufficient to act on the urate of ammonia, then the uric acid is deposited as gravel or calculus; if the supply of oxygen be somewhat greater, but still deficient, oxalic acid is the result, and mulberry calculus occurs; but, if much exercise be taken and abundance of oxygen supplied, the oxidation of the uric acid is completed, and nothing is left but urea or carbonate of ammonia.

5903. "This explains the true cause of uric acid and mulberry calculus to be a deficiency of oxygen; it also explains why uric acid calculus is followed by mulberry calculus in those who remove from the town to the country, where more exercise is taken; and from these considerations we may see how valuable are the results which will flow from a thorough investigation of all departments of animal chemistry.

5904. "The urine of the herbivora differs from that of man, in containing, besides urea, hippuric acid when they are at rest or stall-fed, and benzoic acid when they are in full exercise, and when consequently more oxygen is supplied. Liebig has shown, that, if to five times the formula of blood, we add nine atoms of oxygen, we have the elements of six atoms hippuric acid, nine atoms urea, three atoms choleic acid, three atoms ammonia, and three atoms water; and that, if to five times the formula of blood we add forty-five atoms oxygen, we obtain the elements of six atoms benzoic acid, thirteen and a half atoms urea, three atoms choleic acid, fifteen atoms carbonic acid, and twelve of water. Moreover, two atoms proteine, with two atoms of water, contain the elements of six atoms allantoine (found in the urine of the foetal calf), and one atom choloidic acid, which is supposed to be the same as the meconium.

5905. "The bile of the herbivora is much more abundant than that of the carnivora, an ox secreting, according to Burdach, 37lbs. of bile daily. As the waste of matter in the herbivora is but limited, it is obvious that it cannot supply all the bile, and consequently a great part of it must be derived from the starch and other nonazotized constituents of their food, which lose oxygen, and enter into combination with some azotised product of the decomposition of compounds of proteine.

5906. "In order to show how this is possible, Liebig points out that the elements of two atoms of proteine, with those of three atoms uric acid and two atoms oxygen, amount to the same sum as six atoms hippuric acid and nine atoms urea; while, if to five atoms starch we add two atoms hippuric acid and two atoms oxygen, the sum is equal to two atoms choleic acid and twenty atoms carbonic acid.

5907. "Again, if the elements of proteine and starch, oxygen and water being present, undergo transformation, and mutually affect each other, the products of this metamorphosis may be urea, choleic acid, ammonia, and carbonic acid. Thus:

5 atoms	protaine,	5	(C <sup>42</sup> N <sup>6</sup> H <sup>24</sup> O <sup>14</sup> )	=	C <sup>210</sup> N <sup>30</sup> H <sup>120</sup> O <sup>70</sup>
15	"	starch,	15	(C <sup>12</sup> H <sup>10</sup> O <sup>10</sup> )	= C <sup>180</sup> H <sup>150</sup> O <sup>150</sup>
12	"	water,	12	(H O)	= H <sup>12</sup> O <sup>12</sup>
5	"	oxygen,			= O <sup>5</sup>
The sum is					= C <sup>400</sup> N <sup>30</sup> H <sup>282</sup> O <sup>237</sup> .

And

9 atoms	choleic acid,	9	(C <sup>26</sup> N H <sup>26</sup> O <sup>11</sup> )	=	C <sup>234</sup> N <sup>9</sup> H <sup>237</sup> O <sup>99</sup>
9	"	urea,	9	(C <sup>2</sup> N <sup>2</sup> H <sup>4</sup> O <sup>2</sup> )	= C <sup>18</sup> N <sup>18</sup> H <sup>36</sup> O <sup>18</sup>
3	"	ammonia,	3	(N H <sup>3</sup> )	= N <sup>3</sup> H <sup>9</sup>
60	"	carbonic acid,	60	(C O <sup>2</sup> )	= C <sup>60</sup> O <sup>120</sup>
The sum is					= C <sup>420</sup> N <sup>30</sup> H <sup>282</sup> O <sup>237</sup>

5908. "The reader will observe that these equations are given, not as representing what is actually proved to occur, but only to show how such changes may be conceived on ordinary chemical principles. But it is to be borne in mind, that all the necessary substances meet in the circulation; proteine and starch from the food, oxygen in the arterial blood, and that water is never absent: while the resulting products are the chief constituents of the secretions and excretions; viz. carbonic acid, excreted by the lungs; urea and carbonate of ammonia, excreted by the kidneys; and choleic acid, secreted by the liver. (Animal Chemistry, 150 et seq.)

5909. "We have thus seen how the carbon in the form of choleic acid or bile, may be obtained in a state most favourable for its oxidation or combustion. But, if the supply of oxygen be deficient, the choleic acid may by a partial oxidation yield hippuric and lithofellic acids, just as we have seen that uric acid, partially oxidized, yields oxalic acid; for two atoms choleic acid + 10 atoms oxygen are equal to two atoms hippuric acid, one atom lithofellic acid, and fourteen atoms water. Thus one species of biliary calculus, identical with the bezoar stones found in the herbivora, may have an origin similar to that of the mulberry calculus, both arising from a deficient supply of oxygen. (Liebig.)

5910. "Soda is necessary to the formation of bile, and is supplied in the form of common salt. Where the supply of soda is defective, the metamorphosis of proteine can yield only fat and urea. If we assume for fat the empirical formula C<sup>11</sup> H<sup>10</sup> O, then two atoms proteine, with twelve atoms water, and fourteen atoms oxygen, in all C<sup>98</sup> N<sup>12</sup> H<sup>24</sup> O<sup>44</sup>, are equal to six atoms urea, six atoms fat, and eighteen atoms carbonic acid. If we assume fat to be C<sup>12</sup> H<sup>10</sup> O, a similar result may be traced; and the composition of all fats lies between these two empirical formulæ. Now, it is worthy of observation, that, if we wish to fatten an animal, we must carefully avoid giving much salt in its food. (Liebig.)

5911. "As another point of connection between the products of the metamorphosis of bile and of the constituents of urine, in addition to the possibility already mentioned of both being derived from the oxidation of proteine, it may here be remarked, that three atoms taurine and three atoms ammonia are equal to one atom uric acid, one atom urea, and twenty-two atoms water; and that one atom taurine and one atom ammonia are equal to one atom allantoine and seven atoms water. (Liebig.)

5912. "It may further be noted that one atom uric acid, fourteen atoms water, and two atoms oxygen, correspond to two atoms taurine and one atom urea; or, if two atoms water be added, to two atoms taurine and two atoms carbonate of ammonia. Moreover, one atom alloxan and ten atoms

water are equal to two atoms taurine; and one atom taurine contains the elements of two atoms oxalic acid, one atom ammonia, and four atoms water. (Liebig.)

5913. "As alloxan is a product of the oxidation of uric acid, and as it has been shown above to be related to taurine, that is, to bile, it would be very important to study its action on the system. It might probably act beneficially in some diseases of the liver. It may be safely administered in considerable quantity. (Liebig.)

5914. "In the urine of the carnivora we find soda in moderate quantity, combined with sulphuric and phosphoric acids. This soda was contained in their food, and, after contributing to form the bile, has been secreted by the kidneys. But it is never sufficient to neutralize the acids produced, and consequently we find much ammonia along with it, while the urine is acid.

5915. "But in the urine of the herbivora soda is present in far larger quantity, and combined with carbonic, hippuric, or benzoic acid. This shows that the herbivora require a far greater amount of soda than is contained in the amount of blood daily consumed, which in them is small; and this soda is obtained from their food, and employed in producing their abundant bile.

5916. "The plants on which the herbivora feed cannot grow in a soil destitute of alkalies; but these alkalies are not less necessary for the support of the animals than of the plants. The soda is found in the blood and bile; and the potash is now known to be absolutely essential to the production of caseine, that is, the secretion of milk. In like manner, the phosphate of lime, which is essential to the growth of grasses, is equally essential to the production of bone in the animals which feed on these plants. It is impossible not to be penetrated with admiration of the wisdom which is shown in these beautiful arrangements.

5917. "Let us now consider the changes which the food undergoes in the process of digestion, and we shall observe this process in the carnivora, where it is most simple, as their food is identical in composition with their tissues.

5918. "When the food has entered the stomach, the gastric juice is poured out, and after a short time the whole is converted into a semifluid, homogeneous mass, the chyme. Many researches have been made to discover the solvent contained in the gastric juice, but in vain. It contains no substance which has the property of dissolving fibrine, albumen, &c.; and we are compelled to adopt the opinion of Liebig, according to which the food is dissolved in consequence of a metamorphosis, analogous to fermentation, by which a new arrangement of the particles is effected. As, in fermentation, the change is owing to the presence of a body in a state of decomposition, or motion, which is propagated from the ferment to the sugar by contact; so, in digestion, the gastric juice contains a small quantity of a matter derived from the lining membrane of the stomach, which is in a state of progressive change, and the change or motion is propagated from this to the particles of the food under certain conditions, such as a certain temperature, &c.

5919. "The phenomena of artificial digestion confirm this view. If the lining membrane of a stomach, perfectly clean and fresh, be infused in water feebly acidulated with chlorohydric acid, the liquid acquires no solvent action on albumen; but if the membrane be exposed to the air for some time, or be left in water for a while,—in short, if decomposition be allowed

commence,—then the infusion, if coagulated albumen or fibrine be placed in it, and the whole kept at the temperature of the body, by degrees effects perfect solution or digestion.

5920. "Prout has shown that the gastric juice contains free chlorohydric acid. This is derived from the common salt, the soda of which combines with the albumen or fibrine, while its acid, being set free, at length by its accumulation checks further change. Besides the gastric juice, the only other substance employed in digestion is the oxygen which is introduced into the stomach with the saliva, which from its viscosity encloses a large quantity of air. The chyme then leaves the stomach, and gradually passes into the state of chyle, which resembles blood, except in colour, being already alkaline, not acid like the chyme.

5921. "By means of the circulation oxygen is conveyed in the arterial blood to every part of the body. This oxygen, acting on the tissues destined to undergo change, produces a metamorphosis, by which new soluble compounds are formed. The tissues thus destroyed are replaced by the new matter derived from the food. Meantime, those of the products of metamorphosis which contain the principal part of the carbon, are separated from the venous blood in the liver, and yield the bile; while the nitrogen accumulates, and is separated from the arterial blood in the kidneys in the form of urea or uric acid.

5922. "It has been already mentioned, that vegetables alone possess the power of forming proteine, which they furnish to animals in the forms of albumen, fibrine, and caseine. In the animal body these forms of proteine are employed to yield the different tissues, most of which bear a simple relation to proteine. Thus,—

Fibrine, albumen, caseine, are	-	-	Pr + S + P + salts.
Arterial membrane is	-	-	Pr + 2HO.
Chondrine is	-	-	Pr + 4HO + O <sup>a</sup> .
Hair, horn, &c., are	-	-	Pr + NH <sup>a</sup> + O <sup>a</sup> .
Gelatinous tissues are	-	-	2Pr + 3NH <sup>a</sup> + HO + C <sup>a</sup> .

5923. "It is not meant that these formulæ express the actual constitution of the tissues, but only that they give the proportion of the elements actually present, and show how they might give rise to the tissues. Some of these tissues contain proteine, or at least yield it when acted on by potash: this is the case with hair and horn. But others, as, for example, the gelatinous tissues, although doubtless derived from proteine, do not contain it, and consequently cannot yield any of its modifications. This explains the fact that gelatine alone cannot support animal life. It cannot yield blood or muscular fibre, although it may serve to nourish the gelatinous tissues. See *Gelatine*.)

5924. "Liebig has shown (*Animal Chemistry*, p. 141), that gelatine may be formed from proteine in two ways; either by adding to two atoms proteine three atoms allantoine and three atoms water (which are equal to one atom uric acid, one atom urea, and four of water), or by subtracting from three atoms proteine half an atom choloidic acid, and adding four atoms water. These statements apply to Mulder's formula for gelatine; but as the true formula is still doubtful, they are only mentioned to show the method by which we may hope to arrive at accurate results.

5925. "There is another constituent of the animal body, namely fat, the production of which deserves notice. It is not an organized tissue, but is formed and collected in the cellular tissue under certain circumstances.

These are rest and confinement, that is, a deficiency of oxygen, and an abundance of food devoid of nitrogen. Carnivorous animals are never fat and the herbivora only become so in confinement.

5926. "Now the chief source of fat is starch, or sugar, the composition of which is such, that, if deprived of oxygen, fat remains. If from starch  $C^{12}H^{10}O^{10}$ , we take nine atoms oxygen, there remains  $C^{12}H^{10}O$ , which is one of the empirical formulæ for fat. Or if from starch we remove one atom carbonic acid,  $CO^2$ , and seven atoms oxygen, the remainder,  $C^{12}H^{10}O$ , represents the other empirical formula of fat. We have already seen how fat may be derived from proteine when soda is deficient; and we may here add, that all the elements of food contain more oxygen than fat, in proportion to the carbon. Thus, in albumen, fibrine, and caseine, for 120 eq. carbon there are contained 36 eq. oxygen; in starch, for 120 eq. carbon, 100 eq. oxygen; in sugar and gum, 110 eq. oxygen; in sugar of milk, 120 eq.; and in grape-sugar, 140 eq. oxygen; while in fat there are only 10 eq. oxygen for 120 eq. carbon.

5927. "It is obvious, therefore, that fat can only be formed by a process of deoxidation. But we have seen that it is produced where oxygen is deficient; and it appears, as Liebig has pointed out, that when there is a deficient supply of oxygen, the production of fat, which is the consequence of this deficiency, yields a supply of that element, and thus serves to keep up the animal heat and the vital functions, which would otherwise be arrested. This is another beautiful instance of contrivance, equally simple and wonderful.

5928. "That fat must be formed by the deoxidizing process above alluded to, is proved by the phenomena of the fattening of animals. A goose, tied up, and fed with farinaceous food altogether destitute of fat, acquires, in a short time, an increase in weight of several pounds, the whole of which is fat. Again, the bee produces wax, a species of fat, from pure sugar.

5929. "With regard to the production of nervous matter, which animals alone can form, we see, from its composition, intermediate between that of proteine and fat, that it may be formed, either by depriving proteine of some nitrogenated product, or by adding such a product to fat. Where it is formed we do not know; but it must be formed in the animal body: and Liebig has suggested that the power of the vegetable alkalies to affect the nervous system, may be owing to their composition, which approaches nearer to that of nervous matter than any other compounds. These alkalies may promote or check the formation of nervous matter, and thus produce their peculiar effects.

5930. "In like manner, certain vegetable products analogous to the vegetable alkalies, such as caffeine (or theine) and theobromine, may be supposed, according to Liebig, to promote the secretion of bile, their composition being related to that of some of the products of bile.

5931. "Thus one atom caffeine (or theine), with nine atoms water and nine atoms oxygen, may yield two atoms taurine. Again, one atom theobromine, with twenty-two atoms water and sixteen atoms oxygen, corresponds to four atoms taurine and one atom urea; or one atom theobromine, eight atoms water, and fourteen atoms oxygen, contain the elements of two atoms taurine and one atom uric acid. (Animal Chemistry, 180.)

5932. "Now it is surely very remarkable, that the vegetables containing these compounds, tea, coffee, and cocoa, should be, one or other of them, used by almost all nations to yield a refreshing drink; and it is still more



curious that the peculiar principle of tea should turn out to be identical with that of coffee, as recent researches have demonstrated.

5933. "We may suppose, with some degree of probability, that where the formation of bile, and consequently that of urine, which is connected with it, does not go on as it ought, the use of these beverages, by promoting the secretion of bile, may assist the process of respiration, promoting the animal heat, and, at the same time, contributing to the due performance of all the vital functions. At all events, neither the beneficial and refreshing effects of these articles of diet, nor their relation to bile and urine, can be overlooked; and the universal adoption of the practice of using tea, coffee, or chocolate, is a proof that men have discovered and obtained from different sources the means of producing the same effect.

5934. "The preceding observations are sufficient to show that we may expect, in progress of time, to explain the action of all remedies on chemical principles. The true path has been opened up, and it only remains for experimenters to pursue it with energy and perseverance."

## OF RESPIRATION.

5935. The quotation from Gregory's work being concluded, I subjoin an article which I had prepared on respiration, as it contains some ideas which are not found in the preceding matter, and some objections to Liebig's explanation of the phenomena of that process.

5936. Chemistry demonstrates, that during this process, the volume of the air respired by animals is diminished, but that a portion of the oxygen is replaced by an equal bulk of carbonic acid. Although, at one time, by respectable observers, the volume of this last mentioned gas was alleged not to be uniformly equal to that of the absorbed oxygen, the ratio of the one to the other, being represented as varying with the time of day and the season, not only in different animals, but also in the same animal, later observation seems to have produced a general opinion, which is zealously espoused by the distinguished chemist above mentioned, that the expired carbonic acid is, upon the whole, exactly equivalent to the oxygen consumed.

5937. The prevalence of nitrogen, in animal substances, naturally led to the idea that it might be assimilated more or less during respiration; but experience has led to an opposite opinion; and Liebig has endeavoured to show, that in the nutriment of granivorous animals, there is no deficiency of vegeto-animal matter having as large a proportion of nitrogen as flesh and blood\* (5023).

\* I subjoin the following opinion of Berzelius. Report for 1840, page 313.

"The question has often been put, whether animals assimilate nitrogen during respiration. In examining air which has been breathed by them, it has been found

5938. When first, by the Lavoisierian school, the heat of all ordinary fires was shown to be attributable to the union of oxygen with the combustible employed, the idea naturally followed, that respiration being attended by a like union of oxygen with combustible matter, animal heat ought to be ascribed to this source. Many objections to this explanation of the origin of animal heat were subsequently urged, and, among others, the fact that the heat of the lungs, *the fire place*, is no higher than remoter parts of the animal frame.

5939. To remove this objection, Crawford suggested that the capacity for heat, of arterial blood, being greater than that of venous blood, caloric was taken up by the blood in one state, to be evolved when in the other. This suggestion respecting the relative capacities for heat, of arterial and venous blood, has not been supported by subsequent experience; and another view of the subject has been taken, which renders it quite consistent that the temperature should not be peculiarly high in the lungs.

5940. It is supposed that the blood merely *absorbs* oxygen in the lungs, but that this oxygen is carbonized during its circulation, and thus causes heat to be given out in all parts of the system. The carbonic acid thus produced, on reaching the lungs in combination with the venous blood, is exchanged for oxygen, and consequently expired with the breath.

5941. Liebig conceives that the iron in the hematin of the red globules is held by the arterial blood, in the state of hydrated sesquioxide; but in the capillaries, the sesquioxide passing to the state of protoxide, by yielding oxygen to the carbon in the blood, combines with the car-

that in some cases a deficit of nitrogen has ensued, in others an excess, while in others, again, the proportion has remained unchanged. Yet rigorous experiments have proved, that the nitrogen of respired air is quite passive, and cannot be assimilated during respiration: moreover, that the blood, in common with all other liquids in contact with the air, contains nitrogen and oxygen in the proportion in which they are present in the gaseous mixture employed; so that when a mixture, containing more nitrogen, is respired, a greater quantity is absorbed. When the mixture, under like circumstances, has an inferior quantity of nitrogen, this principle is given out by the blood. It may be assumed, that experiments have completely decided that the proportion of nitrogen in the animal frame is altogether independent of the quantity of air respired."

It does not, however, appear to me to be true, that all liquids in contact with air take up its ingredients in the same proportion; or if they do, that they continue to hold them in that proportion, uninfluenced by the chemical affinity between the constituents and oxygen.

carbonic acid thus produced, and gives rise, in the venous blood, to a carbonated protoxide.

5942. When the venous blood reaches the lungs, the protoxide exchanging carbonic acid for oxygen, this gas is expelled with the breath, while the regenerated sesquioxide is again, by union with water, reconverted into a hydrate. The well known change of hue which follows the transfer of the blood from the veins to the arteries, through the pulmonary organs, seems to be considered as a collateral consequence of these chemical reactions. Yet this change does not appear to me sufficiently accounted for, since no such alteration of colour can be produced by the transformation of a carbonated protoxide of iron to a hydrated sesquioxide. Moreover, the fact that no peculiar elevation of temperature takes place on the surfaces where the venous blood meets the breath, seems to me inconsistent with Liebig's explanation, since the heat must be extricated in the space where the iron is peroxidized.

5943. Upon the whole I now think as I have for forty years, whatever other opinions may have prevailed, that there must be a degree of heat derived from respiration proportioned to the quantity of oxygen converted into carbonic acid; but with all due deference for Liebig, I do not agree with him, that it is possible to give a satisfactory explanation of this process upon purely chemical affinities, such as exist independently of vital power. It appears to me that nature has the power, within certain limits, of making chemical affinities to suit her own purposes, and can therefore cause the oxygen to be absorbed, the carbon to combine therewith, and the heat to be given out when and where the processes of vitality require it. If nature have not the alleged power, how does it happen that, out of the heterogeneous congeries of elements existing in the egg, the bill, the claws, the feathers, the bones, the blood, and flesh, are made to appear at the various stations, at which their presence is requisite, for the existence of a young bird?\*

\* Mr. Winn, (L. and E. Phil. Mag. 174,) considers the extension and contraction of the fibrous tissues of the arteries, during pulsation, as among the causes of animal heat. It is well known that caoutchouc grows warm when rapidly extended; and Mr. Winn found a portion of the aorta of an ox to be capable of a similar rise of temperature, when, during two minutes, it was made to undergo turgescence, and collapse similar to that which takes place during pulsation. To have decided this ques-

5944. Liebig cites the following interesting facts. active man expires 13.9 ounces of carbon, and daily sumes, in the same time, 37 ounces of oxygen = 51 cubic inches, or about 223 gallons. Reckoning 18 respirations per minute, there must be 25,920 consumed day, and consequently  $\frac{44}{22} = 1.99$ , or nearly two cubic inches of oxygen in each respiration. In one minute therefore, there are added to the blood  $1.99 \times 18 = 35.82$  cubic inches of oxygen, weighing rather less than two grains.

5945. In one minute, ten pounds of blood pass through the lungs, measuring 320 cubic inches, among which being divided, there must be one cubic inch of oxygen in each pound of blood nearly.\*

5946. Ten Hessian pounds of blood = 76,800 grains in the arterial state, contain  $61\frac{1}{4}$  grains sesquioxide of iron; if in the venous state,  $55\frac{1}{4}$  of protoxide.† 6 grains difference, is the quantity of oxygen which the iron of venous blood can acquire in the lungs, which, deducted from twelve grains, the whole quantity of oxygen absorbed leaves 5.60 grains requiring some other means of absorption. But  $55\frac{1}{4}$  grains of protoxide of iron would take 73 cubic inches of carbonic acid, which is double the volume that the  $35\frac{1}{8}$  of oxygen can generate.

5947. One glaring defect in this part of the explanation arises from the admitted fact, that nearly one-half of absorption of oxygen is unaccounted for; 5.60 in two parts.

#### OF FERMENTATION.

5948. Certain spontaneous changes which ensue in organic substances by which they are more or less decomposed or resolved into new combinations, have been generically designated under the name of fermentation.

5949. For a long time only three kinds of fermentation had been recognised, called, severally, the vinous, the acetous, and the putrefactive; now we have several others added to the list, among which are the serine, and the viscous or lactic.

5950. The production of cyanhydric acid (1323) by the reaction

tion, the author should have shown that heat might be permanently caused by extension and contraction either of caoutchouc or the ox artery. But were it demonstrated that heat could be thus permanently generated, there would be no difficulty in explaining how the organic substances employed could thus give heat. It involves the question of the materiality of caloric, since, if material, permanent supply could not be derived from an isolated strip of caoutchouc.

\* Stated upon the authority of Muller. "Physiologie, Vol. 1, p. 345."

† Deduced from the Researches of Denis Richardson and Nasse, Handwörterbuch der Physiologie, Vol. 1, p. 138. Note.—Measures and weights are Hessian

ausine with amygdaline (3055), that of the oil of mustard by myrosine and myronic acid (5091), are, by Boutron and Fremy, considered as cases of fermentation; and to these, it seems, we may add the generation of nitrin, which is alleged to be the effect of a species of fermentation promoted the leaf of the tobacco plant after it has been gathered.

5951. To the saccharine, the vinous, acetous, and viscous or lactic fermentation, allusion has already been made in treating of starch (4082); of cane sugar (4057); of alcohol (5578); of lactin (4070); acetic acid (197); lactic acid (5215).

### *Of the Saccharine and Vinous Fermentations.*

5952. *The saccharine fermentation* is exemplified in the change which takes place in the mash or wash of the distiller, by which the starch of the grain,  $C^{12}H^{10}O^{10}$ , takes two atoms of water,  $2HO$ , to form dry grape sugar,  $C^{12}H^{12}O^{12}$ .

5953. *The vinous fermentation* ensues in all cases where alcohol is produced by an internal change in organic solutions. By some chemists, it is supposed that alcohol is produced only when grape sugar is present at the start, or generated subsequently; since it is alleged that cane sugar and other saccharine substances must be converted into grape sugar before they can enter into the vinous fermentation. It has been stated, that by this fermentation an atom of grape sugar is resolved into the elements of two atoms of alcohol and four atoms of carbonic acid (5578).

5954. The juice of the apple, the pear, or the grape, at any temperature above  $50^{\circ}$ , spontaneously enter into the alcoholic fermentation. This is ascribed to the existence, in them, of a vegeto-animal matter, which being not oxidized, afterwards mysteriously causes the sugar to be resolved into alcohol and carbonic acid, as already stated (5578). The preservation of fruits and other organic substances by heat, in well closed vessels, is ascribed to the prevention of that oxidizement of the vegeto-animal ferment, which is the necessary precursor of fermentation.

5955. In the case of wort as prepared in breweries, there is great difficulty in inciting a proper vinous fermentation, without the assistance of yeast arising from a preceding process. Yet during every well conducted fermentation, a large quantity of this substance has to be thrown off. The thorough performance of this process, called cleansing, has always been known to be necessary to the flavour of the beer; but Liebig alleges that it so lessens the liability to acetification, and that by a process practised in Bavaria, the yeast being more thoroughly removed by deposition, such a superiority was attained as respects insusceptibility of sourness, that large premiums were offered in other German states for those who should succeed in imitating that process. This consists in the exposure of the beer, in open shallow vessels, to atmospheric oxygen, at a temperature below  $50^{\circ}$ , at which the vegeto-animal matter which forms the yeast, is oxidized and precipitated at a temperature too low for that simultaneous conversion of the alcohol into acetic acid, which would be the consequence of a higher temperature under like circumstances.

5956. During fermentation there is a commensurate attenuation of the liquor, of which the extent may be ascertained by the hydrometer. In fact, this instrument and a thermometer are indispensable to enable a manufacturer to conduct well any fermenting process. The hydrometer shows that diminution of density which measures the gain in alcohol. This attenua-

tion is estimated roughly by the change in the froth or head, which, in the presence of saccharine matter is abundant so as to envelope the carbonic acid, rises high, but gradually falls as the solution becomes thin until, in consequence of the formation of the yeast, a new head rises, free of that viscid matter.

*Of the Acetous Fermentation, a Process of Acetification.*

5957. To *acidify*, signifies to produce any species of acidity; but the application of the word *acetify* is confined to those processes by which acetic acid is produced, of which there are several.

5958. Of the processes alluded to, that by which fermented and spirituous liquids are made to generate acetic acid in the form of vinegar, has been designated as the acetous fermentation being accompanied by an apparent intestinal reaction between the ingredients in the liquid mixture or solution which undergoes this acetifying process. This fermentation differs from the vinous in requiring an extraneous supply of atmospheric oxygen, which, as has been mentioned, ethyl is changed into acetyl by the addition of two atoms of hydrogen, and the acetyl is afterwards acidified by the acquisition of two more such atoms (5197), so that, from a hydrated oxide of ethyl, a hydrated trioxide of acetyl arises.

5959. Yet alcohol, whether strong or dilute, does not, per se, undergo the change just described. The presence of some substance which attracts oxygen from the air, appears necessary to cause its acetification. Thus dilute alcohol and water do not ferment; but a mixture of one part of honey and one of crude tartar to thirteen of alcohol and one hundred of water, will, in warm weather, produce vinegar in a few weeks (5197). The change effected in the alcohol may be understood from the formula already given.

5960. The usual method of producing vinegar by the exposure of liquor in open vessels, demonstrates that the necessity of atmospheric oxygen has been learned in practice. Latterly, the process has been greatly expedited by allowing the liquor to fall, in drops, upon the shavings of beech wood, the temperature being kept up nearly to  $100^{\circ}$ . According to Liebig, in this way one part of spirit of wine, containing eighty per cent. of alcohol, with about five parts of water and  $\frac{1}{1000}$ th of yeast of honey or other ferment, may be converted into vinegar in from twenty-four to thirty-six hours.

*Of the Lactic or Viscous Fermentation.*

5961. This has only of late been treated as a distinct process, although its effects have long been known to those engaged in the manufacture of sugar and fermented liquors, whether for distillation or drink. The rancidity in beer, ale, or porter, the premature acidity of the distiller's wash are referrible to the process under consideration. It is this fermentation which supervenes in the absence of yeast, or whenever any nitrogenous substance, oxidized by the air to a certain extent, is present. It differs from the vinous, in giving rise to lactic acid, mannite, and a viscid matter, usually called ropy, with hydrogen, as well as carbonic acid gas. Many years since I was surprised to find the gas given out by cider in a state of intense fermentation, take fire, and discovered, on examination, inflammable gas to be hydrogen.

5962. Agreeably to a statement given in Graham, 803, an atom of m

as, and an atom of lactic acid, are equal to one atom of grape sugar, minus an atom of oxygen.

5963. I am under the impression that all the four fermentations may sue either successively, or, to a certain degree, simultaneously. Thus, her starch or lactic may be converted into grape sugar. This product may be partially changed into alcohol, and in part into lactic acid and mannite (4074); while a portion of alcohol simultaneously generated, may be undergoing acetification.

5964. Each fermentation has its appropriate ferment. Thus diastase cures the saccharine fermentation, yeast the alcoholic, oxidized diastase, caseine or curd, the lactic; while the scum or sediment, called mother of negar, promotes the acetic fermentation. It is the object of the vintner, the brewer, and distiller, to permit only the two first fermentations, the alcoholic especially, to which the saccharine is accessory. This object is cured by taking great care to have the juice or wort simultaneously subjected to a temperature between 60° and 70°, and a limited exposure to air, with the addition of the proper ferment, where this is necessary; while, by great cleanliness, the presence of any matter capable of inducing the acetic or lactic fermentation is avoided. Much liquor is spoiled by the substitution of the *viscous* for the *alcoholic* fermentation.

5965. In a memoir published in the *Annales de Chymie*, 3d series, 2d vol. 257, Messrs. Boutron and Fremy have made some interesting observations respecting the generation of lactic acid in milk. Oxidized caseine (123) is considered by them as pre-eminent in efficacy as a ferment, for the lactic fermentation, by acting on the sugar of milk or lactic; but in consequence of an affinity for the generated acid, the oxidized caseine forms with it an inert compound which precipitates.

5966. The generation of lactic acid requires the presence both of lactic acid and free oxidized casein. Of course, in order to increase the production of lactic acid, it was found necessary to add an additional quantity of lactic acid to milk, but to renew the efficiency of caseine, it was found sufficient to saturate the lactic acid as often as the production of this acid was arrested by the precipitation of the oxidized casein.

5967. Diastase, after being exposed a few days to the air, becomes capable of inducing the viscous or lactic fermentation. The membranes of the stomach of a dog or calf, or the substance of a bladder, by a like exposure, were found capable of inciting the fermentation in question. Yet animal matters, in appearance similarly prepared, are productive of different results, as respects the proportions of mannite, of viscous matter, of lactic acid, or alcohol, generated. The means by which the various ferments, respectively, produce their appropriate changes are involved in the greatest obscurity. Some important additions have been made to our knowledge, as respects the facts. The ferments have all been shown to be vegeto-animal matter in a state of oxidizement, and an analogy seems to have been established between their influence and that of some other agents, which have been considered as acting by what has been called catalysis, which is a new name given by Berzelius to an old mystery. It has long been known that there are two modes by which chemical changes are to be excited. In one of these, the presentation of one or two extraneous elements causes decomposition and recomposition, by the reactions between the elements so presented, and those subjected to alteration, as in the various cases of elective affinity (508, &c.). In the other mode, substances undergo transformations by being made to rearrange their constituents into one or more new

combinations, by the presence of other bodies with which they do not combine, and which, in some cases, undergo no change themselves. In the last mentioned mode of reaction that the name above mentioned has been applied. Yet, under this head, processes have been crudely associated which have discordant features. Liebig indiscriminately gives a common explanation to these processes, and to those of fermentation, so far as might be crudely referrible to catalysis.

5968. The following processes are associated by this distinguished chemist under one rationale:—*the solubility acquired by platina by being alloyed with silver: the catalyzing influence of platina sponge or platina black: the explosion of fulminating powders by slight causes: the reciprocal decomposition of bioxide of hydrogen and oxide of silver: the agency of nitric oxide in the generation of sulphuric acid: the action of ferments.*

5969. To me it seems that there is a great diversity in the characteristics of the processes thus alluded to. In the case of the platina alloy there is at least an atom of silver for each atom of platina in actual combination with this metal; and the change which the latter undergoes is precisely the same as that to which the former is subjected.

5970. In the case of platina sponge causing the formation of water, or of platina black, causing the acetification of alcoholic vapour, the catalyzing agent undergoes no change itself; and it enters not into chemical combination either with the materials, or the products. Liebig ascribes the result in this instance to the alternate absorption and subsequent evolution of oxygen by the powder; since, after exposure to the gas, it may, by exhaustion, be made to give up a portion. But the agency of this metallic mass cannot differ, in this case, from that in which it causes the pure elements of water to combine, and in which, if absorption take place, it is not confined to oxygen more than to hydrogen. But the fact established by Faraday, that hydrogen and oxygen may be made to unite by a well cleaned plate of platina, seems irreconcilable with the idea that absorption is the mean of its accomplishment. But if absorption be not operative in one case, how can it operate in the other?

5971. In this, as in all other cases, Liebig seems to overlook the all important agency of electricity in the phenomena of nature. I should infer, that the metal most probably acts by altering the electrical polarity, and consequent association of imponderable matter. But having assumed, that during the dehydrogenation of alcohol by atmosphere oxygen in the presence of platina black, this powder is alternately endowed with the power to take it from the air, and to impart it to that of which the attraction for oxygen, under the circumstances, is too feeble to take it from the same source, this distinguished philosopher proceeds to make the inference that honey, mother of vinegar, and other substances, promotive of acetification, act in the same way by absorbing oxygen from the air, and abandoning it to hydrogen. But if agreeably to the view above presented, platina black does not act by absorption, no argument, founded on the agency of that substance, will justify the idea that absorption avails in other cases; and it should be recollected, that platina black is very active when perfectly free from moisture, while honey, yeast, mother of vinegar and other substances which cause acetification, have no attraction for oxygen in the absence of water: moreover, that the necessity for moisture in the preparatory oxidizement of gluten, caseine, diastase, and other organic substances, which by exposure in a humid state acquire their capacity



et as ferments, is inexplicable. Water is powerful both as a catalyzer and as a solvent.

5972. Before referring to the absorption of oxygen by honey, as a ground for explanation founded on the analogy of platina black, the ability of water to cause honey to absorb oxygen should be first elucidated.

5973. An electric spark or any ignited body, a wire made incandescent by a galvanic discharge, has an influence analogous to platina sponge, of which the minutest particle is sufficient to cause ignition throughout an inflammable mixture, however large. There is, in this respect, an analogy between the explosion of inflammable gaseous mixtures and those of gunpowder, and of other fulminating powders, of which some, as it is well known, detonate by percussion or friction, or any cause adequate to derange the equilibrium of their particles. In the cases last mentioned, the change produced is the same, whatever may be the exciting cause, and the minutest portion of the congeries being made to undergo the change, is of itself competent to produce a like result as respects the whole.

5974. The property which bioxide of hydrogen, and the oxide of silver, or bioxide of lead, have, of undergoing an explosive deoxidizement in consequence of mere superficial contact, is evidently another case, since the reaction is reciprocal. In the solution of the alloy of platina with silver, one body induces another to undergo the oxidizement to which it is itself subjected. In the case of the bioxide of hydrogen and oxide of silver, two bodies, both prone to deoxidizement, reciprocally induce that species of change. But in this phenomena there is no third body to perform a part analogous to that of the nitric acid.

5975. In case of ferments there is not only the power to produce a change, but also to produce the particular changes by which sugar, alcohol, and acetic or lactic acid, and mannite, are respectively generated. Moreover, these bodies are themselves undergoing an oxidation or decomposition which is necessary to their power; but this change is not like that which they induce. Hence, obviously, they operate differently, either from the platina sponge, or platina black, or from the silver in the alloy formed by it with platina. Liebig conceives, that this increased solubility of platina by union with silver, is at war with electro-chemical principles, agreeably to which, any metal in contact with another metal, relatively electro-positive, becomes less susceptible of attack. But this is not alleged of two metals in chemical combination, but of masses in contact, or having a metallic conductor extending from one to the other. I am surprised that Liebig should find the mystery of catalysis lessened by the solution of the alloy alluded to, when it must be evident that if the oxidation of one atom were a sufficient reason why another atom combined with it should be oxidized, an alloy of gold with silver ought to be soluble. Whereas, it is known that the common process of parting is founded on the utter insolubility of gold when so alloyed.

5976. Liebig alleges that there can be no doubt that the acidification of alcohol is of the same order as the reaction by which nitric oxide provokes the formation of sulphuric acid in the leaden chamber (1019), in which process the oxygen of the air is transferred to sulphurous acid by the intervention of the bioxide of nitrogen, since, in like manner organic substances associated with spirit of wine, absorb oxygen, and bring it into a particular state which renders it liable to be absorbed.

5977. But in the case thus cited, for every equivalent of acid formed, an equivalent of the bioxide combines first with an equivalent of oxygen, and

in the next place with an equivalent of the sulphurous acid, for pound which is decomposed by water into sulphuric acid and the bioxide. There appears to me to be no analogy between this that of the influence of matter existing in no equivalent proportion which cannot be shown to form a definite chemical compound acetyl or hydrogen. It is not represented that, in the vinous fermentation, any union, either transient or permanent, takes place between the sugar and those of the ferment: on the contrary it is the oxidation and precipitation of the yeast proceeds, *pari passu* with the alcoholification.

5978. As to all the processes referred to for illustration, as to the fermentation, which they are alleged to resemble, it appears that Liebig and his disciples have been too sanguine of their capacity for adequate elucidation.

5979. Respecting changes of the kind above described as occurring in the fermentation of sugar, Dr. Kane uses the following language:—"The elements of a compound are retained together in certain molecular arrangement, because they are there satisfied; but it is natural to suppose that whilst the elements remain the same, their affinities for each other might be just as well satisfied by a different molecular arrangement." This language is not held more reasonably, were this variation in arrangement accompanied by no concomitant acquisition of chemical properties; but is it reasonable to consider the difference between sugar, and the alcohol and carbonic acid into which it is resolvable, as arising merely from molecular arrangement? Can the active influence of alcohol upon the animal nerves be explained by the situations respectively occupied by its three ultimate components, carbon, hydrogen, and oxygen, of which it consists? And if the union of oxygen with the ingredients of gluten could, by inducing consequent mechanical impulses, cause the hydrogen and carbon atom of water to unite with the elements of sugar, and to separate the alcohol and carbonic acid as above mentioned, how can that movement consequent rearrangement of the ponderable particles, explain the acquisition of new properties, of which the combining atoms, or the previously containing them, were destitute? That the presence of diastase induces the fermentation of alcohol, and that diastase determines the fermentation of sugar, is admitted; but I am surprised that any philosopher could conceive, that without first ascertaining upon what the difference between the properties of alcohol and sugar is dependent, we can understand how the fermentation is caused. Liebig infers that a body in the act of decomposition, may communicate a movement to the atoms of another compound, so that gluten in the state of oxidation, in which the yeast induces sugar,  $C^{12} H^{11} O^{11}$ , existing in the same liquid, to the elements of water, making  $C^{12} H^{12} O^{12}$ , separating into four atoms of carbonic acid and two of alcohol.

5980. Adopting the same views as Liebig, Dr. Kane alleges that the slow decomposition of diastase communicates to the molecule of sugar a thousand times its weight of starch, the degree of motion necessary for their rearrangement, and the appropriation of the elements of water to the site for the formation of starch sugar."

5981. It is perfectly evident, that the particles of the catalyzed body are in some way so affected by the catalyzing body as to be put into motion, of reaction, which had not otherwise ensued; but that this is accomplished merely by imparted motion appears to me to be a surmise destitute

sibility. The fact that the weight of the diastase requisite to saccharify starch is so very small, as is alleged by Dr. Kane, evidently renders it extremely improbable that it acts by creating any mechanical disturbance. Yet this respectable chemist is so completely carried away by this idea, that he proceeds to make the following remark: "*This law, of which the simplest expression is that where two chemical substances are in contact, any motion occurring among the particles of the one may be communicated to the other, is of a more purely mechanical nature than any other principle yet received in chemistry; and when more definitely established by succeeding researches, may be the basis of a dynamic theory in chemistry, as the law of equivalents and multiple combination expresses the statical condition of bodies which unite by chemical force.*"

5962. I perfectly agree in opinion with the author of these suggestions, as to the *purity of the mechanical attributes of the principle on which they are founded*, but cannot on this very account deem them competent to explain the phenomena on which he conceives them to bear.

5963. As the mechanical influence of the motion of bodies is as the weight multiplied by the velocity, is it conceivable that any movement in the particles of one part, by weight, of diastase, can be productive of analogous movements in two thousand parts of starch?

5964. The idea that yeast might owe its power to animalcules, suggested itself to me more than thirty years ago, and seems to have some support from the fact, that fermentation only thrives within the range of temperature compatible with animal life. Latterly, its activity has been ascribed to the power of extremely minute vegetables. Kane, while admitting the existence in yeast of *a vast number of globular bodies, possibly animalcules*, treats the idea as untenable, because the weight of the alcohol and carbonic acid is greater than that of the sugar employed. But if the union of water with the elements of the sugar, can add to the weight of the products, without the assistance of animalcules, wherefore should *their* agency be inconsistent with an augmentation from the same source? But the weight of the alcohol and carbonic acid are just equal to that of the sugar, if this be assumed to be in the state of sugar of grapes (5578).

5965. Independently of any agency of this kind, which seems even more probable in the case of some species of infection, than in that of fermentation, I conceive that the present state of our knowledge does not allow of our comprehending the means by which bodies, whether organic or inorganic, are endowed with the powers ascribed to catalysis; but that we have great reason to believe that these powers, as well as all the properties which ultimate elements acquire by diversity of association, as in compound radicals, are due to the same source as the phenomena of galvanic and statical electricity.

5966. It is well known, that although pure zinc is not susceptible of oxidation by exposure to dilute sulphuric acid, yet that, when containing minute proportions of other metals, as in the case of commercial zinc, it becomes liable to rapid oxidation by the same reagent. This Faraday explained by the electro-chemical influence of the comparatively electro-negative metallic particles distributed throughout the mass of the zinc, which he conceived to be productive of as many local galvanic circuits with corresponding currents. This explanation has, I believe, been universally sanctioned, and was consistent with the previous discovery of Sturgeon, that when, by amalgamating the surface with mercury, a metallic communica-

tion was made between the electro-positive and electro-negative metallic particles, so as to prevent the formation of electrolytic currents through the oxidizing liquid, the zinc became nearly as insusceptible of union with oxygen, as when in a pure state.

5987. Nevertheless, either when pure, or when amalgamated, the zinc was found oxidizable by diluted sulphuric acid, provided it were made the element of a galvanic pair.

5988. The facts above mentioned having been recalled to the attention of the scientific reader, I beg leave to inquire whether the influence thus ascribed by Faraday to the electro-negative metallic particles has not a greater analogy with that of a ferment, than those which have been brought forward by Liebig, Kane, and others, with a view to explain the influence of that class of agents upon mechanical and chemical principles? Wherefore may not the distribution of nitrogenated substances throughout a mass of inorganic matter, operate as do the metallic impurities in commercial zinc? The existence of a powerful voltaic series in the gymnotus and other electrical fishes, shows that the substances which enter into the composition of animal matter are, when duly associated, as capable as metals of forming the elements not only of simple, but of complex galvanic circuits.

### OF THE PUTREFACTIVE FERMENTATION.

5989. To that species of spontaneous decomposition which is called putrefactive, animal substances, in general, are much more disposed than vegetable; and the effluvia which they emit, during the change, are much more offensive. It seems as if certain affinities which exist between the ultimate elements of many vegetable and animal substances, although suspended by the inexplicable powers of vitality, resume their operation as soon as those powers cease, with greater or less activity, according to the nature of the substance, and the influence of heat and moisture.

5990. The presence of phosphorus and sulphur contributes greatly to the fetor of animal putrefaction. On the other hand, few animal substances are susceptible of the vinous or acetous fermentation.

5991. Liebig seems disposed to obliterate the line which was heretofore drawn between fermentation proper, and putrefaction. He alleges, that a practice the principal mean of discrimination has been the diversity of odour. To fermentation has been ascribed all processes attended by transformations, resulting from internal reaction, which are attended by no unpleasant smell; whereas fetid processes, in other respects analogous, have been designated as putrefactive: but that, in point of fact, the presence of nitrogen seems to have been the usual associate of substances prone to what is called putrefaction.

5992. But so far as fetidity is an essential attribute of putrefaction, the presence of hydrogen, with sulphur and phosphorus, seems to me more essential than that of nitrogen, since this element is much more rarely the vehicle of fetid emanations, and, when isolated, is remarkably inodorous.

5993. The presence of water, or of its elements, seems indispensable to the spontaneous decomposition of organic substances. In no instance is either the vinous, acetous, or putrefactive fermentation induced, in substances which are perfectly dry. The effect of desiccation in preserving meat and fruits, sufficiently proves the correctness of this allegation. It is probably, by paralyzing the activity of the water in meat, that salt favours

its preservation; and the beneficial influence of sugar upon preserves may in like manner be explained.

5994. The peculiar efficacy of water in promoting fermentation, of whatever kind it may be, rests, as I conceive, on the same basis as its peculiar efficiency in promoting electrolysis. And until we are capable of comprehending the part it performs in the one case, we shall vainly endeavour to understand the duty which it fulfils in the other.

5995. When, in addition to water, nitrogen is a constituent, the tendency to decomposition is increased. Gluten and yeast, which contain nitrogen, are very liable to an extremely offensive putrefaction. To their deficiency in this principle, Dr. Turner ascribes the indisposition of oils to putrescency; but I conceive their freedom from water, and incapacity to unite with it, to be the true cause.

5996. The insusceptibility of the vegetable alkalies to decomposition, while containing both hydrogen, oxygen, and nitrogen, may arise partly from their sparing solubility in water, and partly from the predominance of carbon in their composition (5506).

5997. Although heat, to a certain extent, is necessary to putrefaction, it may be arrested by a high temperature, as well as by frost. In the one case, water, being vaporized, is removed; in the other, being congealed, becomes inert.

5998. Thenard alleges that water is not decomposed during putrefaction, but, on the contrary, generated.

5999. Besides water, we may enumerate ammonia, with carbonic, acetic, and sulphydric acid, also carburetted and in some cases phosphuretted hydrogen, among the products of putrefaction.

1. The first part of the document is a letter from the

author to the editor, dated 10th March 1954.

2. The second part is a letter from the editor to the

author, dated 15th March 1954.

3. The third part is a letter from the author to the

editor, dated 20th March 1954.

4. The fourth part is a letter from the editor to the

author, dated 25th March 1954.

5. The fifth part is a letter from the author to the

editor, dated 30th March 1954.

6. The sixth part is a letter from the editor to the

author, dated 5th April 1954.

7. The seventh part is a letter from the author to the

editor, dated 10th April 1954.

8. The eighth part is a letter from the editor to the

author, dated 15th April 1954.

9. The ninth part is a letter from the author to the

editor, dated 20th April 1954.

10. The tenth part is a letter from the editor to the

author, dated 25th April 1954.

11. The eleventh part is a letter from the author to the

editor, dated 30th April 1954.

# INDEX

TO

## THAT PORTION OF THIS COMPENDIUM

WHICH RELATES TO

## INORGANIC CHEMISTRY.

**Absorption of æriform fluids, 222—by charcoal, 223—of heat, 6—of light, 79—of nitric oxide, 183—produces heat, 6, 223—by silk and woollen stuffs, 223.**

**Acetate of ammonia, 5—of baryta, 276—of copper, 314—of lead, 90, 318—of zinc, 332.**

**Acetates in general, 459.\***

**Acid, acetic, 314, 318\*—alumina acts as an, 268—antimonie, 346—antimonious, 346—arsenic, 335, 336\*—arsenious, 91, 335, 336—auric, trioxide of gold, 291—benzoic, 329—boric, 250—bromic, 129—carbonic, 225, 229—chloriodic, 133—chloric, 126—chlorohydric, 141, 157, 162, 163—strength of, 164—chlorous, 123, 124, 125—chloroplatinic, 294—chloroplatinous, 294—chloroxycarbonic, 233\*—chloroplatinic and chloroplatinous, 232—chromic, 353—croconic, 232\*—cyanhydric, 153, 246, 278, 367\*—cyanic, 243\*—cyanoferrie, 243—cyanoferrous, 243, 246—cyanuric, 243\*—defined, 357—dephlogisticated marine (i. e. chlorine), 117—fluoboric, 258—fluohydric, 134, 256—fluosilicic, 134, 251, 257—fluohydroboric, 257—fluohydrosilicic, 257—fulminic, 243\*—hydrochloric, 160, 162, 163, 285—hydrofluoric, 256—hydrocyanic, 244—hyperiodic, 133—hypochlorous, 123, 362—hyponitrous, 183—hyposulphuric, 137—hyposulphurous, 137—iodic, 131, 133—iodohydric, 131, 159, 165—iodous, 133—manganic, 354—margaric, 202\*—mellitic, 232—muriatic or chlorohydric, 160—nitric, 190, 191—nitro-muriatic (aqua regia,) 291, 292—nitrous, 184—nitroso-nitric, 213—oxalic, 231\*—oxy, or per, manganic, 354—oxymuriatic, 119†—perchloric, 127—phosphoric, 216—phosphorous, 216—**

**prussic (cyanhydric), 246, 248\*—selenhydric, 171—selenic, 141, 142—selenious, 141, 142—silicic, 253—stearic, 202—succinic, 329—sulphydic, 166, 168\*—sulphocarbonic, 234—sulphocyanhydric, 245—sulphuric, 139, 140—sulphurous, 137—tartaric, 346\*—tellurhydric, 171—tungstic, 355.**

**Acidifiable metals, 261.**

**Acidity, 201.**

**Acids, amphydric, 304—halohydric, 159, 304—organic, 109\*—relation to positive pole, 109—with mercury, 304—reaction of, with litmus, 203.**

**Action, mechanical, of the lungs, 29.**

**Æriform or elastic fluids, 105.**

**Ærolites, 324.**

**Affinity, simple and double elective, or complex, 89, 90.**

**Agency of water, 151.\***

**Aggregation, attraction of, 83.**

**Air, 11, 18, 19, 22, 23, 24, 26, 41, 103, 154, 174—cold and cloudiness consequent to rarefaction of, 37—condensation of, 27—elastic reaction of, 22—pump, 21, 24—rarefaction of, 23—weight of, 14, 104.**

**Alcohol, 101, 239.\***

**Alloys, 263.**

**Alkalies, fixed, 278, 288—organic, 109.\***

**Alkanet, as a test for alkalies, 203.†**

**Alkaline earths, 270, 271.**

**Alum, 264, 266.**

**Alumina, 267—hydrate of, 266, 267.**

**Aluminate of magnesia, of zinc, 265.**

**Aluminium, 268.**

**Amalgams, 301.**

**Amalgam of ammonium, 209.†**

**Amalgam of gold, 290—of potassium, sodium, 208, 209.**

**Amalgams of calcium, barium, strontium, 272.†**

\* See Index to Organic Chemistry.

† See Emendation, end of Index, page xix.

\* See Index to Organic Chemistry.

† See Index to Electricity.

- Amethyst**, 265.  
**Ammonia**, 90, 92, 205, 206, 207\*—reaction with oxide of silver, or that of copper, 90—nitrate of, 180.  
**Ammoniacal nitrate of copper**, 91—of silver, 91.  
**Ammonium**, 208—chloride of, 209—reaction of chloride with lime, 92.  
**Amphigen bodies**, 108.  
**Analysis of gaseous mixtures**, eudiometer for, 185, 228—volumescopie, Volta's eudiometer for, 148—of elephant gas, 238.  
**Animal charcoal**, 222\*—respiration, 227\*—substances, 370.\*  
**Anhydrous antimonie acid**,  
   ric acid, 139.\*  
**Annealing**, 254, 255, 263.  
**Anode**, 197.†  
**Anthracite**, 220.  
**Antimony**, 89, 344—bichloride of, 347—bisulphide of, 349—crocus of, 348—glass of, 348—golden sulphur of, 348—liver of, 348—oxysulphide and hydrated oxysulphide of (kermes mineral), 348—precipitated sulphide, 348—perchloride of, 347—regulus of, 344—selenide of, 349—sesquichloride, 347—sesquioxide, 345, 347, 349—sesquisulphide, 347, 348—sulphide, 348.  
**Aqua ammonie**, 208.  
**Aqua marina**, 269.  
**Aqua regia**, 291.  
**Aqueous vapour**, 31 to 41; 151 to 155.  
**Arbor Diane**, 86—Saturni, 86.  
**Argand lamp**, 65.  
**Argentine flowers of antimony**, 345.  
**Aridity of the air**, 155.  
**Arsenic**, 334—compounds of, 338\*—means of detecting, 340—poisoning by, 340—selenides of, 339—sulphides of, 338—reactions of, 338, 339.  
**Arsenates and arsenites**, 337.  
**Assay furnace**, 299.  
**Athermane and diathermane bodies**, 56.  
**Atmosphere**, 19, 174; see *Air*—eudiometer for analysis of, 214.  
**Atomic theory**, weights, 95, 96, 97.  
**Attraction**, 2, 83, 88.  
**Attrition**, ignition by, 61.  
**Aurate of ammonia**, 291.  
**Avena sensitiva**, hygrometer by, 39.  
**Azote (nitrogen)**, 172.\*  
  
**Barium**, 271, 272, 276—process for evolution of, 272.†  
**Barometer and barometric column**, explanation of, 14 to 26.  
**Barometer gauge**, 26.  
**Baryta**, or barytes, 275, 276.  
**Basacigen elements**, 108, 261.  
**Basidity**, 109.  
**Basifiable metals**, 261.  
**Base metals**, 260.  
**Bellows**, of and forge fires, 65.  
**Benzoic acid**, 329.  
**Benzoate of lead**, 317.  
  
**om.**  
 ...ide of mercury, 307.  
 ...uret of hydrogen, 235, 240.  
 ...uret of nitrogen or cyanogen, 30.  
 ...ride of antimony, 345.  
 ...rine ether, or chlorohydrate of chloroform of acetyl, 233, 241.\*  
 ...chloride of mercury, 301, 306.  
 ...chromate of lead, 317.  
 ...anide of mercury, 241, 246, 38.  
 ...troguret of carbon (fire damp), 26.  
 ...ide of lead, 319.  
 ...ide of mercury, 307.  
 ...y salts, 358.  
 ...late of potash, 231.  
 ...de of lead, 316.  
 ...de of manganese, 354.  
 ...de, 136.  
 ...de of barium, 276.  
 ...de of calcium, 275.  
 ...de of hydrogen, 156—of mercury, —of tin, 320.  
 ...sphates, 367.  
 ...ath, 322, 323.  
 ...phide of antimony, 345—of bismuth, —of carbon, 234—of iron, 225—of mercury, 301.  
 ...rate of potash, 281, 369.  
 ...r almonds, oil of.\*  
 ...men, 220.  
 ...minous coal, 220.  
 ...ck oxide of copper, 312—of iron, 35.  
 ...of manganese, 354—of mercury, 301.  
 ...aching, 119, 361.  
 ...hing salt, 172, 361.  
 ...ade, 331.  
 ...pewpipe, 65.  
 ...pewpipe, compound, or hydro-oxygen, 66.  
 ...Blue stone, or blue vitriol (sulphate of copper), 313.  
 ...Boiling point, 31 to 37, 52.  
 ...Bone, or ivory black, 221.  
 ...Borates, 367.  
 ...Borax, 367.  
 ...Boron, 249, 250.  
 ...Boruretted hydrogen, 284.  
 ...Boruret of potassium, 284.  
 ...Brass, 89, 263.  
 ...Brazil wood, test for alkalinity, 203.  
 ...Bromide of carbon, 233—of cyanogen, 30.  
 ...—of iodine, 133—of mercury, 304—of selenium, 142—of silver, 220—of sulphur, 140.  
 ...Bromine, 128—in mineral springs, 12.  
 ...Bronze, 89.  
  
 ...Cadmium, 352.  
 ...Calamine (silicate or carbonate of zinc), 331.  
 ...Calcina, or lime, 273—alkalinity of, 203.  
 ...Calcination, 274.  
 ...Calcium, 272, 300—apparatus for evolution of, 272.  
 ...Caloric, 3, 5, 14, 74, 263.  
 ...Calomel, 304.

\* See Index to Organic Chemistry.

† See Index to Electricity.

\* See Index to Organic Chemistry.



rimotor.  
 sel coal, 230.\*  
 itchouc, 239.\*  
 ohydrogen, 235, 240, 241.\*  
 on, 220.  
 onates, 367.  
 onate of cadmium, 352—of lead, 277,  
 7, 318—of lime, 274—of magnesia,  
 l—of zinc, 331.  
 onic acid, liquid, solid, 225, 226, 229,  
 ).  
 onic oxide, 224.†  
 urrets of potassium, 283.  
 steel, 325.  
 ode, 197.†  
 entation of iron, 325.  
 am, 262.  
 se, 277, 319.  
 ybeate springs, 326.  
 neleon mineral, 354.  
 coal, 220, 221, 223.  
 nical affinity, 83, 88—attraction, 83—  
 rivalents, 94—implement, 21—reac-  
 n, 2.  
 nical symbols, 96.  
 nistry, definition of, 1.  
 racid, 268.†  
 ral, 232.†  
 rate, 362.  
 rate of potash, 361, 363.  
 ride, 122, 285.  
 ride of aluminum, 268—ammonium  
 l—boron, 251—bromine, 130—of gl  
 ium, yttrium, thorium, 285—gol..  
 l—hydrogen, 160—iodine, 133—iro  
 l—mercury, 304—of lithium, de  
 scence, solubility of, in alcohol, 2  
 f nitrogen, 128—phosphorus, 12  
 l—potassium, 127—selenium, 142—  
 con, 254—silver, 299—sulphur, 1  
 horium, 270, 285—yttrium, 285.  
 rides of carbon, 233—of sulphur, 140.  
 rine, 108, 117, 119, 157, 241—hydrate  
 156.  
 rite or hypochlorite of lime, 172.  
 robes, 200.  
 rohydrate of the chlorobase of cop-  
 r, 314.  
 rosalts, 370.  
 rohydrates, 285.  
 mates, 319.  
 mium, 350.  
 abar, 300.  
 rns, hydropneumatic, 105, 106.  
 es of metals, 260.  
 nification, 108, 109, 110, 198. *See let-  
 on Berzelian nomenclature, &c.*  
 , 266.  
 lt, 251, 354.  
 sion, 83, 91.  
 , 220.  
 , 27, 62, 68, 73—by combination, 73—  
 vaporization, 60—radiation of, 50, 55.  
 ring matter of the blood, 245.\*  
 urs, different rays, 78, 79.  
 mbium, 354.

Cork, 239—to ascertain specific gravity  
 of, 100.  
 Combustibles, foundation of idea of, 198.  
 Combination, 61, 91.  
 Combustion, 113, 118, 136, 194, 251, 310.  
 Complex or double elective affinity, 90.  
 Compound, or hydro-oxygen, blowpipe,  
 66.  
 Concave mirrors, 53.  
 Condensation, 27 to 30.  
 Condensation of gases by charcoal, 222—  
 for illumination, 240.  
 Condenser, 27.  
 Congelation of water, 67 to 73—of car-  
 bonic acid, 229—of prussic acid, 248—  
 of sulphur, bismuth, antimony, zinc, 86.  
 Copper, 310, 311, 312.  
 Corindon Telesie, 265.  
 Corrosive sublimate, 305.  
 Croconate of potash, 232.  
 Crocus of antimony, 348.  
 Cryophorus, 71, 72.  
 Crystallization, 83, 84.  
 Crystallized potash, 282.  
 Crystallography, 84.  
 Crystals of Venus, 314.  
 Cubic galena, 141.  
 Cuprum ammoniatum, 313.  
 Cupel and cupellation, 297.  
 Culinary paradox, 32.  
 Cyanates, 368.  
 Cyanide, or bicyanide, of mercury, 241,  
 307.  
 Cyanide, cyanure, or cyanuret, of potas-  
 sium, 370—silver, 299—zinc, 333—iron,  
 242.  
 Cyanobases, 200.  
 Cyanoferate of potassium, 243.  
 Cyanoferite of potassium, 243, 247.  
 Cyanogen, 108, 157, 241, 242.  
 Cyano salts, 370.  
 Cyanures, cyanurets, or cyanides, 287, 370.  
 Dalton on vapour, 40.  
 Damaak steel, 326.  
 Daniell's blow-pipe, erroneously so called,  
 67.  
 Decayed wood, light from, 76.  
 Decoloration by charcoal, 222—by prote-  
 chloride of tin, 322.  
 Decomposition of ammonia, 207—of water,  
 152.  
 Decrystallization, 87.  
 Definite proportions, 83, 93.  
 Dephlogisticated marine acid, (chlorine,) 117.  
 Derbyshire spar, (chloride calcium,) 251,  
 256.  
 Desiccation of air, means of effecting,  
 70—of the skin, 154.  
 Detection of arsenic, 340.  
 Deuto carbohydrogen, 235, 237.  
 Deutoxides defined, 136.  
 Deutoxide of hydrogen, 156.  
 Diacetate of lead, 318.  
 Diamond, 220.  
 Diaspore, 266.

\* See Index to Organic Chemistry.

† See Index to Electricity.

\* See Index to Organic Chemistry.

Diathermane, and athermane, bodies, 56.  
 Dicarburet of hydrogen, 236.  
 Dichloride of carbon, 233.  
 Dichloride of copper, 314.  
 Dioxide, disulphide of lead, 319.  
 Differential thermometer, 13.  
 Dilatation by heat, 9.  
 Dioxide defined, 136.  
 Dioxide of lead, 316.  
 Disinfecting power of charcoal, 222.  
 Disinfection by hypochlorites, 361, 362.  
 Dispersion of light, 78.  
 Disulphide of copper, 311, 315.  
 Dolomite, 271.  
 Double elective, or complex affinity, 90.  
 Double oxysalts, 368.  
 Double salts of metals, 261.  
 Double silicates, 368.  
 Drummond's lime light, so called, 67.  
 Dutch gold leaf, combustion of, in chlorine, 119.  
 Ductility of metals, 263.  
 Dyeing, 267—mordants for, 267.\*  
 Dynamic electricity, 82.†

## Earths, 264.

Ebullition, 32—by cold, 32.  
 Effervescence, 43.  
 Elasticity, 15 to 44.  
 Elasticity of metals, 263.  
 Electricity, see separate treatise on.  
 Electro magnetism.†  
 Electrometer and electroscope.†  
 Electro-negative metals, 261.†  
 Electrophorus, 58.†  
 Electro-positive metals, 261.†  
 Emerald, 269.  
 Epsom salts, 89, 271, 356.  
 Equivalents, 94.  
 Essential oils, 241.\*  
 Ether, 209.\*  
 Ether, chloric, perchloric, explosive, 128.\*  
 Etherine, 236.\*  
 Euchlorine, 124, 361.  
 Ethiop's mineral, 300—Euclase, 269.  
 Eudiometer, 185, 238—of Volta, 148—sliding rod, 175, 176, 185.  
 Eudiometry, 148, 184, 213.  
 Evaporation, 40, 41—by air, 41—cold produced by, 41, 68 to 73.  
 Everitt's process for cyanhydric acid, 247.  
 Evolution of iodine,  
 Exception to the law that chemical reaction requires fluidity, 92.  
 Exceptions to the law that liquids expand by heat, 9.  
 Exhaustion, 43.  
 Expansion of fluids, 10, 30—liquids, 8—solids, 6—supposed exception to the, 7—theory of, 31—water, 9.  
 Explosive power of steam, 37.  
 Extreme pressure, vaporization of liquids under, 37.  
 Explosion of fulminating mercury, 5—by high steam, 37—mechanical action inducing decomposition, 62—of chlorous

—oxychloride of  
 with hydrogen,  
 -hydrogen with oxygen, 146—  
 gas with oxygen, 239.

copper, Kupfer nickel, 351.

ir, 268, 357.

potassum tart, 368.

ruasiate, or cyanate of potash, 37.

rrite of potassium, 242.

inous minerals, 324.

or feculent emanations neutralised,  
 360.

F of charcoal, &c., 222.

ry, cinder, 328.

damp, 235.

, 162—of hydrogen, 146—reddened  
 , strontia, 277.

wers of sulphur, 135—antimony, 36—  
 zinc, 331.

Fluids, aeriform, 10, 14 to 44, 105. See  
 Gases.

Fluoride of arsenic, 338—bismuth, 24—  
 calcium, 212, 256—chromium, 253—le-  
 , 134, 255—silicon, 255—lead, 39—  
 nury, 308—silver, 299—zinc, 33  
 dles, 370.†

lts, 370.†

rate of hydrogen, 258.†

lumbate of potassium, 354.

on drate of potassium, 258.†

or acinate of potassium, 269.

ne, 108, 134, 157, 259.

ne acids, or fluacids, 157.

F licate of hydrogen, 370.†

lborate of potassium, 270.

black, white, crude, 322.\*

fires, 65.

coal, 220.\*

Fowler's solution, 337.

Freezing of mercury, 71, 230—mixtures,  
 73, 230—water, 68, 73.

French alum, 266.

Friction, ignition by, 60.

Frigorific mixtures, 73.

Fulminates, 368.

Fulminating gold, 206—mercury, 303—  
 silver, 206.

Fulminate of mercury, 368.

Fusible carburet of iron, (cast iron.) 35

Fusion of platina, 68.

Gadolinite, 269.

Gahnite, 265.

Galena, 141, 315.

Galena argentiferous, 277.

Galvanism.†

Gases, table of specific gravities of, 104—  
 of equivalent weights and volumes, 109

Gaseous ammonia, 205—chlorohydric acid,  
 162—sulphydric acid, 160—sulphureous  
 acid, 130.

Gaseous mixtures, eudiometrical analysis  
 of, 148, 175, 185, 224—influence of platina on, 206.

\* See Index to Organic Chemistry.

† See Index to Electricity.

\* See Index to Organic Chemistry.

† See Essays and Letters on Nomenclature.

‡ See Index to Electricity.

- ghting, 239.  
 neters, 106, 107.  
 ussac on volumes, 107.  
 an silver, (packfong,) 352.  
 ite, 246.  
 g, 290.†  
 , 251, 254, 297, 368.  
 formed by fused borax, 251.  
 er salt, 88, 89, 356.  
 na, 268, 269.  
 na fluacid of, 269.  
 nium, 268.  
 290.  
 n sulphur of antimony, 348.  
 and silver coin, 263.  
 meter, 85.  
 rd's extract, 318.  
 meter, 102.  
 ty, specific, 100, 102, 103.  
 vitriol, 326.  
 um, 85, 357.  
  
 ite, 141.  
 en bodies, or elements, 108, 202.  
 l salts, 356.  
 ning metals by refrigeration by the  
 mer, 263.  
 47, 48, 49, 62, 64—capacities for, 44  
 y condensation, 63—for chemical  
 poses, 64—latent, 4—by solution, 62  
 adiation of, 52—specific, 44.  
 carbohydrogen, 236, 240.  
 etate of lead, 318.  
 pressure boiler, 35.  
 steam, 35.  
 geneous attraction, 83.  
 stone, 322.  
 acids, 157. See *Acids, halohydric*.  
 argyrum precipitatum album, 309—  
 do bichloride of mercury.\*  
 te, 151.  
 te of alumina, 266, 267—of carbon,\*  
 —of chloral, 232—of chlorine,\* 156  
 lime, 274.  
 te of lithia, 284—of potash, 136, 280  
 soda, 281.  
 ated bioxide of tin, 320—dioxide of  
 per, 314—protosulphide of iron, 330  
 binitrate of bismuth, 322.  
 c ether, oxide of ethyl, 238, 273.\*  
 gen, 143, 156, 160, 206.\*  
 gen, polysulphide of, 170.  
 ometers, 101.  
 pneumatic cisterns, 105.  
 sublimite, Howard's, 305.  
 ous protochloride of iron, 329.  
 ometer of Daniell, 155.  
 ometers, 39.  
 ometic process of Dalton, by the dew-  
 st, 155.  
 chlorite of lime, 361.  
 nitrites, 365.  
 nitrous ether, 236.\*  
 sulphates, 366.  
 sulphites, 366.  
  
 Ice, 10, 70, 71, 74, 163.  
 Ignition, galvanic, 58, 59.  
 Illustration of equivalents, 95.  
 Implement, chemical, 21.  
 Imponderable substances, 3.  
 Indigo, 202.\*  
 Influence of air on apparent weight of  
 bodies, 103.  
 Influence of pressure on the bulk of air, 28.  
 Influence of solution on chemical reac-  
 tion, 92.  
 Infusions, hygrometer for, 101.  
 Ink, 329.\*  
 Inorganic chemistry commenced, arrange-  
 ment of, in treating, 107.  
 Inorganic substances, 107.  
 Insects, light evolved by, 76.  
 Insoluble chlorides, pretensions to the sa-  
 line character, 356.  
 Insoluble oxalates, 232.  
 Insoluble oxides, 356.  
 Insoluble sulphides, 366.  
 Instrument for the inflammation of small  
 portions of gas, 219.  
 Iodacids, 157.  
 Iodide of arsenic, 338—bismuth, 324—cy-  
 anogen, 245—gold, 202—iron, 330—  
 lead, 319—mercury, 307—silver, 299—  
 sulphur, 140—tin, 321—zinc, 333.  
 Iodides of carbon, 233.  
 Iodine, 108, 130, 131, 134, 297.  
 Iodine in sea salt, 286.  
 Iodo salts, 370.  
 Iodous acid, 133.  
 Iridium, 293, 297, 351.  
 Iron, 91, 245, 324—with acids, 328—with  
 carbon, 263—with gold, 328—wire, 181.  
 Isomeric bodies, 217.  
 Isomorphous substances, 84.  
  
 Kermes mineral, 348.  
 Kernels of bitter almonds, 246.\*  
 Kupfer nickel, 351.  
  
 Laboratory thermometer, 12.  
 Lakes, 267.\*  
 Lamp, Argand, 65, 235.  
 Lamp enamellers, 66.  
 Lamp without flame, 65.  
 Latent caloric, 4.  
 Laurel water, 246.  
 Lavoisier's apparatus for recomposition of  
 water, 153.  
 Lead, 315—reagents by which it may be  
 precipitated from its solutions, 317.  
 Lead water, 318.  
 Lepidomene, 284.  
 Leslie's thermometer, 13.  
 Light, 3, 75, 76, 77, 78, 79.  
 Light, chemical effects of, 80.  
 Light carburetted hydrogen, 236.  
 Light, sources of, 76—polarization of, 80,  
 81—without caloric, 76.  
 Lime, 92, 273, 274—with silicic acid, 275  
 with oxides, 275—with water, 275.  
 Lime light, 67.

\* See Index to Organic Chemistry.

† See Index to Electricity.

\* See Index to Organic Chemistry.

Liquefaction of carbonic acid, 229.  
 Liquefaction of chlorohydric acid  
 163—of cyanogen, 241—of nitro-  
 ide, 181.  
 Liquids, calorific in, 50.  
 Liquid chlorohydric, or muriatic acid,  
 163.  
 Liquid sulphurous acid, 138.  
 Lithia, 284.  
 Lithium, 284.  
 Litmus, 119, 268.  
 Liver of antimony, 348.  
 Loss of gas by condensation, 240.  
 Luna cornea, 299.  
 Lunar caustic, 300.  
 Lungs, action of, 29.  
 Lustre of metals, 263.

Magistry of bismuth, 323.  
 Magnesia, 270.  
 Magnesite, 271.  
 Magnesium, 270.  
 Magnesian alumina, 267.  
 Magnetic influence of nickel, 351.  
 Magnetic oxide of iron, 326.  
 Malate of lead, 317.  
 Malleability of metals, 263.  
 Malleable iron, 326.  
 Manganese, 138, 354.  
 Manganic acid, 354.  
 Manufacture of oil of vitriol, 193.  
 Marble, 273, 357.  
 Margarinic acid, 202.\*  
 Marsh's apparatus, 343.  
 Matter, 1, 3.  
 Massicot, 316.  
 Maugham's blowpipe, so called, 68.  
 Mechanical division, 223.  
 Mechanico-chemical agency of charcoal,  
 223.  
 Media of refraction, 79.  
 Merconate of lead, 317.  
 Melting ice by combustion of carbon, 222.  
 Menachanite, 355.  
 Mercury, 91, 300, 301.  
 Mercury, frozen, 230.  
 Mercurial salts, 301.  
 Mercurio-pneumatic cistern, 105.  
 Metallic crystals, 87.  
 Metallic oxides, 206.†  
 Metals, 197, 262, 263.  
 Metals of alkalis, 284.  
 Metals of earths, 264, 284.  
 Metals, expansion of, 6, 7.  
 Metals proper, 261.  
 Metamerism, 244.  
 Meteoric iron, 324.  
 Mineral crystals, 87.  
 Mineral waters, 130.  
 Minium, 316.  
 Moisture in air, 154.  
 Moisture in clay, 266.  
 Molybdate of lead, 354.  
 Molybdenum, 354.  
 Moon, light of, 76.\*

\* See Index to Organic Chemistry.

† See Essays and Letters on Nomenclature.

le, 299.  
 rate of ammonia, 92.  
 rate of lime, 275.  
 theline, or methyl, 235\*—chloride  
 of, 235.\*  
 tha, 209, 229, 283.\*  
 thaline, 235, 240.  
 the naphtha, 241.\*  
 the protosulphide of iron, 330.  
 the acetate of copper, 314.  
 the nitrates, 364.  
 the phosphates, 367.  
 on light, 75.  
 the, 351—spongy, 297.  
 the of ammonia, 180—of copper, 311  
 of cobalt, 268—of lead, 317—of iron,  
 of silver, 299—of zinc, 332.  
 tes, 364.  
 tes, 365.  
 gen, 172, 173, 174, 179, 283.  
 oxide (nitrous air of Priestley), 181.  
 us oxide, 179—liquefied, 181.  
 et, or amiduret, of potassium, 283.\*  
 et, or amiduret, of sodium, 283.\*  
 et, or amiduret, of copper, 311.  
 metals, 260, 261.  
 elature, 122, 136, 157, 158, 184.  
 hausen, sulphuric acid of, 139.  
 ous compounds of carbon, 235.

lian, 269.

ures, 327.

Odour, alliaceous, of phosphorus, 311—of  
 arsenic, 342.

Odour of selenium, 140, 141.

Oil of turpentine, 229, 238.\*

Oils, fixed, volatile.\*

Ointment, mercurial, 300.

Olfactory nerves peculiarly affected by  
 selenhydric acid, 171.

Olefiant gas, hyduret of acetyl, 188, 235,  
 238.\*

Ores of zinc, 352.

Organic acids, 109\*—alkalies, 109.

Osmiate of soda, 351.

Osmium, 297, 351—alloys of, 351.

Osmiuret of iridium, 351.

Oxacid of gold, 291.†

Oxacids, 157, 158.

Oxalate of copper, 232—iron, 232—lead,  
 317—lime, 232—magnesia, 232.

Oxalis acetosella, 231.

Oxibases, 258, 259.

Oxidability of metals, 263.

Oxide of boron, 250—bromine, 123—cal-  
 cium, 352—calcium, 273—cobalt, 354  
 —glucinum, 260—iridium, 351—lith-  
 ium, 284—magnesium, 270—magnesi-  
 263, 32—of molybdenum, 354—nickel,  
 1-2—nitrous, 181—of osmium, 351—se-  
 lenium, 141—silicon, 253—tellurium,  
 113—thorium, 270—titanium, 353, 355  
 —yttrium, 263—zirconium, 259.\*

\* See Index to Organic Chemistry.

† See Index to Electricity.

**Oxides of antimony**

336, 337—barium, 277—bismuth, 2  
calcium, 273, 275—chlorine, 123—  
mium, 352—copper, 312—gold, 5  
hydrogen, 156—iron, 325, 326—io  
133—lead, 316, 317—manganese, 1  
mercury, 302, 303—nickel, 352—o  
gen, 179—phosphorus, 215—potas  
283—platinum, 294—silver, 296—so  
dium, 283—strontium, 277—sulphur,  
137—tin, 320—zinc, 331, 332.

**Oxybase of ammonium**, 209.

**Oxychlorate of potash**, 127—of barytes,  
281—of ethyl.\*

**Oxychloride of antimony** 345—of bis  
muth, 323—of mercury, 306.

**Oxygen**, 106, 110, 111, 112, 113, 114, 115\*  
—acids, 157.

**Oxygenated water**, 156.

**Oxyhydrogen blow-pipe**, 66—eudiometer,  
176.

**Oxysalts**, 359.

**Oxysulphide of antimony**, 349—of tellu  
rium, 143.

**Oyster shells**, 274.

**Packfong**, (German silver,) 352.

**Palladium**, 350—alloys of, 350—sponge,  
297.

**Palm glass**, 38.

**Paracyanogen**, 242.

**Paradox**, culinary, 32, 33.

**Particles**, 1.

**Peach leaf**, 246.

**Pearl ash**, 280.

**Pencil of solar light**, 76.

**Perbromide of iodine**, 133—of phosphorus,  
217.

**Percarburet of potassium**, 283.

**Perchlorates**, 364.

**Perchloride of antimony**, 120, 345—of cy  
anogen, 245—of iodine, 133—of phos  
phorus, 217.

**Percussion**, heat produced by, 60.

**Percussion powder**, 368.

**Periodide of carbon**, 233.

**Perkins on steam**, 37.

**Peroxide of barium**, 277—of calcium, 275  
—of copper, 311—of potassium, 283—of  
silver, 209—of sodium, 283—of stron  
tium, 277—of zinc, 331.

**Perphosphuretted hydrogen**, 218.†

**Persulphide of antimony**, 345—of arsenic  
335, 338—of lead, 319.

**Petalite**, 284.

**Pewter**, 263.

**Philosophic candle**, 147.

**Philogiston**, 196.

**Piston valve volumeter**, 178.

**Phosphate of iron**, 326—of lead, 319—of  
lime, 211—of soda, 211.

**Phosphates**, 366, 367. See *Emendation*,  
end of *Index to Organic Chemistry*.

**Phosphites**, 366.

**Phosphorescent wave**, 76.

**Phosphorus**, 114, 121, 181, 211, 213, 363—  
combustion of, 212—crystallized, 212—  
ignited by radiation, 53—*isomeric acids*  
of, 217—*with gold*, 290.

**Phosphuret of arsenic**, 339—of iron, 326  
—of zinc, 331—of potassium, 283.

**Phosphurets**, 366.

**Phosphurets of mercury**, 309.

**Phosphuretted hydrogen**, 219.†

**Physical reaction**, 1.

**Physiological reaction**, 2.

**Plants require air and water**, 154—*absorb*  
*carbonic acid*, 227.\*

**Platinated asbestos**, 297.

**Platinum or platina**, 293, 294, 295, 297.

**Platinum**, fusion of, 68—*scroll*, 296—  
*sponge*, 74, 296, 297.

**Plumbago**, 220, 223.

**Plumbum corneum**, 319.

**Pneumatic chemistry**, 83.

**Polarization of light**, 80.

**Poles**, negative and positive, 197.\*

**Polymeric**, 235.

**Polysulphuret of hydrogen**, 170.

**Pompholix**, 332.

**Ponderable elements**, 107—*fluids*, 104.

**Porcelain**, 268, 207.

**Porosity of charcoal**, 55, 223.

**Porous bodies**, 223.

**Potash**, 282.

**Potash**, bichromate of, 353—bitartrate and  
bichromate of, 360—manganate of, 354.

**Potassium**, 162, 178, 279—chloroplatinate  
of, 295.

**Powder**, bleaching, 172, 361.

**Precious stones**, 55, 265.

**Precipitated sulphuret of antimony**, 349.

**Preparation of oxygen**, 111, 112—of potas  
sium, 278.

**Pressure**, 28—of the atmosphere, 14, 15,  
18, 33—on fluids, 30, 31—of liquids, 32,  
33—modifies boiling, 34—restrains che  
mical action, 43.

**Prince Rupert's drops**, 255.

**Principal character of acids**, 358—*groups*  
of salts, 358.†

**Prism**, 77, 78, 80.

**Proportions**, definite, 93.

**Protobromide of iron**, 133.

**Protochloride of arsenic**, 335—bismuth,  
323—carbon, 233—copper, 311, 314—  
cyanogen, 245—gold, 291, 292—iodine,  
133—iron, 183, 186, 325—mercury, 301  
306—tin, 320, 327.

**Protocyanide of iron**, 330—phosphuretted  
hydrogen, 318—selenide of copper, 315  
—sulphate of iron, 183, 186—sulphate  
of tin, 320.

**Protosulphide of arsenic**, 335, 338—copper,  
311—gold, 292—iron, 325, 330—lead,  
319—mercury, 301, 308—tin, 321.

**Protioxide of barium**, 277—bismuth, 323—  
calcium, 273—copper, 311—iron, 325,  
326—lead, 316—manganese, 354—mer  
cury, 301—nickel, 352—nitrogen, 179

\* See *Index to Organic Chemistry*.

† See *Index to Electricity*.

\* See *Index to Organic Chemistry*.

† See *Emendations*, p. xi.

- potassium, 280—silver, 298—sodium, 280—strontium, 277—tin, 330—zinc, 331.
- Prussian blue, 330.
- Prussiate of potash, 330.
- Pulse glass, 38.
- Pump, air, 21—condensing, 27—exhausting, 27—forcing, 27—lifting, 27—water, 19, 21.
- Purple powder of Cassius, 291.
- Pyroligneous acid, 235.
- Pyrometer, 6—Daniell's, 7—Wedge-wood's, 8.
- Pyrophorus, 112, 283.
- Pyroxylic spirit, 235.
- Quadroxide, 137.
- Quantity of air in a given space is as its pressure, 29.
- Quartz, 251, 253.
- Quick communication of heat, 52.
- Quicklime, 205, 206, 274.
- Radiant light, 75.
- Radiation of cold, 55—of heat, 55.
- Radiators, 54, 55.
- Radical of an acid or base, the combustible body in, 157.
- Radicals, metallic, 110, 143—non-metallic, 110, 143.
- Radiant heat, 52, 56.
- Rain storms, non-electric, 40.
- Rarefaction, 23, 37, 39.
- Rationale of frangibility of glass, 48—refrigeration of a jet of high steam, 36—diversity of radiating power of, 54.
- Rays, chemical, heating, illuminating, 56, 57, 78.
- Reaction, elastic, of air, 22—intense corpuscular, 196—attractive, 2—repulsive, 2.
- Reaction of particles and masses of matter, 1.
- Reaumur's scale, 12.
- Receiver, exhausted, 22 to 27—condensation of air in, 29.
- Recomposition of water, 153.
- Red cabbage, infusion of as a test, 203.
- Red oxide of copper, 311—of iron, 325—of lead, 354, 316—of mercury, 302.
- Reduction of metals, 263.
- Reflectors, 54.
- Refraction, 76, 78.
- Refrangibility of light, 79.
- Refrigeration, 73, 74, 234.
- Registering thermometer, 12.
- Regulus of metals, 263.
- Relaxation of pressure on air, or rarefaction of, produces cold, 38.
- Remarks on nomenclature, 122, 136 157, 198, 199. See *Essays, letters, &c.*
- Repulsion, 2—repulsive influence of caloric, 3, 9.
- Reservoir for hydrogen, 144.
- Reservoirs, self-regulating, 236.
- Respiration, 29, 227.
- Resistance of air, 28.
- Revival of metals, 263.
- Rhodium, 350.
- Rhubarb, test for alkalies, 203.
- Rochelle salt, 269.
- Rock crystal, 56—salt, 56.
- Roll sulphur, 136.
- Ruby, 265.
- Rumex acetosa, 231.
- Safety lamp, 236, 237.
- Sal alembroth, 307—ammoniac, 394, 38.
- Saline solutions, 191.
- Salinity, 358.
- Salts, 108, 356.
- Salts of the ocean, 270—of potash, 28—of protoxide of copper, 314—of rhodium, 350—of soda, 282.
- Sanctorio's thermometer, 11.
- Saturni arbor, 86, 332, 333.
- Scale of equivalents, 94.
- Scales of iron, 328.
- Scheele's green, 337.
- Scoria, 355.
- Selenacids, 158.
- Selenide of antimony, 349—arsenic, 28—bismuth, 324—iron, 330—lead, 28—mercury, 304—tin, 322—zinc, 332—phosphorus, 217.
- Selenisalts, 369.
- Selenium, 108, 140, 141, 142.
- Selenium acids, or selenacids, 157.
- Seleniurets, or selenides of phosphorus, 217.
- Seleniuretted hydrogen, 171.
- Self-repellent power of caloric, 55.
- Self-registering thermometers, 12.
- Self-regulating reservoir, 58.
- Sensible heat from electricity, 57.
- Sesquibasic phosphates, 367—bromide of phosphorus, 217.
- Sesquicarbonates, 367.
- Sesquichloride of antimony, 345—of arsenic, 335, 335—of carbon, 233—of iron, 325.
- Sesquicyanide of iron, 330.
- Sesquioxide, 137—oxide of aluminum, 268—of bismuth, 323—of cerum, 36—of chromium, 352—of chromium and iron, 352—of manganese, 354.
- Sesquiphosphates, 367.
- Sesquisulphide of antimony, 345, 347—of arsenic, 335—of iron, 325, 330.
- Sexsilicate of lead and potash, 368.
- Shear steel, 325.
- Silica, 253.
- Silicate of alumina, 268—of iron, 325—of magnesia, 271—of potash, 268—of zinc, 331.
- Silicates, 367.
- Silicon, 251.
- Silicuret of potassium, 284.
- Silicurets, 368.
- Silver, 91, 119, 297, 298, 299—arsenide of, 337—arsenite of, 337—chemical vessels, 256—coin, 298.
- Simple affinity, 89—combination, 89.
- Simple valve volumeter, 179.
- Slag, 355.
- Slaked barytes, or hydrate of, 276.

Slaked lime, or *hydrated lime*, of, 92, 274.  
 Sliding-rod gas measure, 178.  
 Smalt, 354.  
 Smell of arsenic, 342—of selenium, 141.  
 Smoky rock crystal, diathermane properties of, 56.  
 Snow and sulphuric acid, 73.  
 Soaps, 202.\*  
 Soda, 92, 286.  
 Sodium, 279, 280, 301—amalgam of—chlorhodate, 350—chloride of, chloroplatinate of, 295.  
 Solar rays, 57.  
 Solar spectrum, 78, 79.  
 Solid carbonic acid, 229—hydrate of chlorine, 119—sulphuric acid, 140.  
 Solids, circulation of heat in, 47—expansion of, 6.  
 Solution, 92, 285—produces heat or cold, 62.  
 Solvent of gold, 119.  
 Sores from chromic acid, 353.  
 Sources of heat, 57, 64.  
 Space, specific heat of, 46.  
 Specific gravity, 83, 98, 100, 101, 103.  
 Specific heat, 44, 45, 98—of gases, 46.  
 Spectrum, 79.  
 Spinelle ruby, 265.  
 Splendid combustion, 113, 114, 115.  
 Spodumene, 284.  
 Spongy iridium, 297—nickel, 297—dium, 297—platinum, 74, 293, 296—dium, 297.  
 Springs of Virginia, 169.  
 Stalactite, 266.  
 Stalactite, calcareous, 226.  
 States of calorific nature, 74.  
 Steam, condensation of, 52—decomposition of, 152.  
 Steel, 263, 325.  
 Steel mill for giving light in mines, 236.  
 Strontia, 92, 277—apparatus for evolving, 273.†  
 Strontium, 271.  
 Subacetate of copper, 314.  
 Subnitrate of silver, 300.  
 Suboxide of arsenic, 335—of potassium, 283—of silver, 299—of sodium, 283.  
 Suction pump, 19, 20.  
 Sugar of lead, 318.  
 Sulphacids, 158, 288.  
 Sulphate of antimony, 365—of baryta, 276, 365—of bismuth, 365—of copper, 313—of lead, 365—of lime, 365—of magnesia, 69, 270—of mercury, 365—of silver, 365—of soda, suspended crystallization of, 88—strontia, 365—thorina, 270—tin, 365—yttria, 365.  
 Sulphates, 365.  
 Sulphide of barium, 276—of cadmium, 352—of copper, 315—of hydrogen, or sulphydric acid, 166, 167—of manganese, 354—of molybdenum, 354—of platinum, 297—of potash, 136—of selenium, 142—of silver, 299—of zinc, 331, 332.  
 Sulphides, 135, 288, 359—of antimony, 349—of arsenic, 338—of iron, 325—of

d. —of mercury, 301—of phosphorus, 37.  
 Sulphur, 169, 299.  
 Sulphur springs, 169, 299.  
 Supersaturated hydrogen, 166, 170. See *Acid, sulphydric*.  
 Supercarbonate of magnesia, 271.  
 Supporters of combustion, 198.  
 Surfaces, radiating, 54.  
 Suroxide, or bioxide, of barium, 276.  
 Symbols, chemical, 96.  
 Sympathetic picture, 169.  
 Synthesis of ammonia, 207—of chlorohydric acid, 160—of nitrous acid, 184.  
 Table of affinity, 92—of equivalents, 189—of freezing mixtures, 73, 74—of metals, 262—of weights of gases, 104—of volumes, 189.  
 Tanno gallate of iron, i. e. ink, 327.  
 Tantalite, 354.  
 Tantalum (see *Columbium*), 354.  
 Tartar emetic, 346, 368.  
 Tartrate of iron and potash, 368—of antimony and potash, 346, 368—of lead, 317—of potash, 282—of potash and soda, sal Rochelle, 369—of soda, 282.\*  
 Tartrates, 368.  
 Telluric acids, 158, 289.  
 Tellurhydrates, 158.  
 Telluribase, 200.  
 Telluride of mercury, 304.  
 Tellurides, 289, 359.  
 Telluri-salts, 143, 369.  
 Tellurium, 108, 142, 157.  
 Temperature and moisture, 154.  
 Tertium quid, 109, 358.  
 Test of arsenic, 343—of chlorine, 119—of copper, 311—of iodine, 131—of potash, 282—of silver, 119, 298—of soda, 282.  
 Tetartocarbonylhydrogen, 236, 240.  
 Theory of atoms, 95—of chlorine, 165—of electro-magnetism, appendix—of Melloni, 56—of phlogiston, 196.  
 Theory of volumes, 187.  
 Thermo-electric batteries, 323.†  
 Thermo-electric pile, 56.†  
 Thermometer of Sanctorio, 11.  
 Thermometers, 10, 14, 36.  
 Thermoscope of Melloni, 56.  
 Thillier's process for congelation of carbonic acid, 44, 230.  
 Thomson's equivalents, 94.  
 Thorina, 269, 270.  
 Thorite, 269.  
 Thorium, 269.  
 Tin, 89, 292, 320.  
 Tinder, 221.  
 Tin, crystalline hydrate of, 321.  
 Tin, hydrated bioxide of, 320.

\* See Index to Organic Chemistry.

† See Index to Electricity.

\* See Organic Chemistry, 5181 to 5193, also 5:28.

† See Index to Electricity.

- Titanium, 355.  
 Topaz, 265.  
 Torricellian experiment, 17.  
 Toughness of metals, 263.  
 Transmission of contagion, 223.  
 Triacetate of lead, 318.  
 Tribromide of gold, 292.  
 Trichloride of gold, 292.  
 Trioxide of gold, 291.  
 Trisulphide of gold, 292.  
 Tritocarbonyl, 235.  
 Tubulated retort, figure of, 161.  
 Turmeric, 203, 277.  
 Turpeth mineral, 303.  
 Tungsten, 355.  
 Type metal, 89.  
  
 Undulations of light, 75.  
 Uranium, 355.  
 Urea, 244.  
  
 Vacuum, 43, 46, 70, 71—Torricellian, 46.  
 Vanadium, 355.  
 Vapour, 40, 47—Berzelius on, 42—of chloride of carbon, 233—ethereal, 47—of iodine, 131—of sulphur, 136.  
 Vaporization, 31, 37, 40—cold produced by, 68—of ice, 71.  
 Vegetable colouring matters, 203—charcoal removes them, 222—destroyed by chlorine, 119—by hypochlorous acid, 124—by hypochlorites, 361.  
 Velocity of sound accelerated in hydrogen, 146.  
 Vinous fermentation, 226.  
 Vitality, a source of heat, 64.  
 Vitriified borax, 356.  
 Vitriolated tartar, i. e. sulphate of potassa, 357.  
 Vitriol, colcothar of, 328.  
 Vitriol, oil of, 139.  
 Vitreous compound of antimony, 348.  
 Voice affected by hydrogen, 147.  
 Volatile alkali, 204—oxide of osmium, 351—oxide of selenium, 141.  
 Voltaic current, action of, on phosphorus, 211.  
 Voltaic electricity,†—power of fishes,†—poles, 109, 197—series, 197.†
- f, 189.  
 microscope, 170, 171.  
 meter, 178.  
  
 r, 150, 151, 153, 154, 257—acts like acid with bases, 151—acts like a base with lime, 274—acts like a base with acids, 151—an absorbent, 119, 121, 127—congelation of, 69—expansion of, frozen by boiling ether, 68—acidified, 231—of crystallization, 67—synthesized, 156—pump, 19—basic, See Organic Chemistry and Appendix, for essays on nomenclature, salt, and mineral theory.  
 Weight of air, 104—of the atmosphere, 14, 18—of gases, 104—of fluids, 104—of steam, 104.  
 whirling in vacuo, 104.  
 weights, atomic, 96, 97.  
 Whirling process, 263.  
 Whirling wheel, 44.  
 White hydrate of iron, 326.  
 White sulphur springs, 199.  
 White oat, beard of, as an hygrometer, 2, 5.  
 White sands from the African deserts, 215.  
 White, 154.  
 White is replete with aqueous vapour, 2, 3—gauze, 236.  
 Weston's equivalents, 94, 95—crystals, 71.  
 White, a peculiar variety of steel, 225.  
 White's apparatus, 163—improved, 225.  
  
 Yttria, 269.  
 Yttrio cerite, 269.  
 Yttrio tantalite, 269.  
 Yttrium, 269—chloride of, 285.  
  
 Zaffre, 354.  
 Zinc, 89, 331—acetate of, 90, 333—carbonate of, 331—cyanide of, 333—fluoride of, 333—iodide of, 333—oxides of, 331—selenide of, 333—silicate of, 331—sulphate of, 331—sulphide of, 331.  
 Zirconion, or zirconium, 259.

† See Index to Electricity.

† See Index to Electricity.



# INDEX

TO

## THAT PORTION OF THIS COMPENDIUM

WHICH RELATES TO

## ORGANIC CHEMISTRY.

ine, 588.

549.

of ammonia, 460—of tungsten,  
of molybdenum, 459—of oxide of  
, 562—of pepsine, 575.

of lead, 459, 460, 496.

oxide of ethyl, acetic ether, 542.  
e, 391.

s fermentation, 596, 598.

or acetule, 377, 392, 547—chloride  
19, 550—chlorohydrate of chloride  
49—oxychloride of, 550—trioxide  
7—trioxide hydrated, 456.

cetic, 379, 456, 458, 547, 597—ace-  
471, 547—aldehydic, 547—allox-  
488—azomeric, 445—benzoic, 382,

450, 476, 492, 588—bromohydric,  
bromosalicylic, 482—butyric, 425

feic, 473—caffee tannic, 473—ca-  
425—caproic, 425—carbonic, 372,

583, 584, 586\*—cerebric, 573—chlo-  
453—chlorochromic, 482—chloro-

ic, 564—chlorosalicylic, 481—cho-  
576, 589—cholic, 577—choloidic,

588—cholopholic, 445—cinnamic,  
450—citric, 461—citraconic, 462—

stearic, 425—crotonic, 425—cyan-  
ic, 375\*—cyanoxalic, 484—cyan-

455—delphinic, 425—dialuric, 490  
idic, 429—erythric, 487—ethalic,

ethero-sulphurous, 537—ethionio,  
fellinic, 577—formic, 471—formo-

alic, 478—formous, 471—fumaric,  
fuming nitric, 449\*—gallic, 455,

glucic, 470—guaiacinic, 464—hip-  
383, 477, 492, 588—humic, 584—

sulphobenzoic, 475—hyposulpho-  
thalic, 475—hyposulphurous, 475—

aliculic, 482—isethionio, 475, 530  
conic, 462—kacodylic, 393—lactic,

568, 598—lignosulphuric, 410—li-

thofellic, 578—malic, 462—margaric,  
425, 447—meconic, 451, 469, 497—me-  
lanic, 481—melassic, 470—mesoxalic,  
488—mucic, 399, 471—mycomelinic,  
488—myristicic, 425—myronic, 597—  
nitric, 453\*—nitroso-nitric, 433\*—nitro-  
salicylic, 482—oleic, 424, 425, 447—oleo-  
phosphoric, 572, 573—oxalhydric, 470—  
oxalic, 372\*—oxaluric, 488—palmatic,  
422—parabanic, 486, 488—paratartaric,  
462—pimaric, 445—pinic, 445—pyro-  
gene, 455—pyroligneous, 440—pyro-  
maric, 445—racemic, 462—ricinic, 425  
—ricino oleic, 425—ricino stearic, 425—  
saccharic, 470—salicyhydric, 479—sali-  
culic, 481—salicylous, 479, 521—salicy-  
lous, 479—stearic, 425, 447—succinic,  
453, 476—sulphoamylic, 396—sulpho-  
cyanhydric, 470\*—sulphoglyceric, 397—  
sulphomethylic, 474—sulphoproteic, 564  
—sulphosaccharic, 475—sulphovinic,  
474, 532—sulphuric, 497\*—sylvic, 445  
tannic, 465, 473—tartaric, 417, 462—  
tartralic, 463—tartrovinic, 474—thionu-  
ric, 488—uramic, 489, 490—uric, 484,  
485, 579—uric anhydrous, 486—valeri-  
anic, 473, 562—xanthoproteic, 564.

Acidifiable radicals, 377.

Acids, bibasic, 454, 456—from gaultheria,  
482—from sugar, 470—monobasic, 454  
—polybasic, 471—pyrogenic, 455—tri-  
basic, 454, 456—volatile, 427.

Aconitia, or aconitine, 512.

Aconitum napellus, 512.

Adjective dyes, 419.

Agedoile, 523.

Albumen, 411, 564, 565, 566—animal, 413,  
415—vegetable, 413, 415.

Alcargen, alcarsin, 393.

Alcohol, 374, 384, 468, 547, 598—amylic,  
561—ethylic, 384—methylic, 552.

\* See Inorganic Chemistry.

\* See Inorganic Chemistry.

- Alcornine**, 528.  
**Aldehyde**, 389, 547, 548—ammoniated, 548—mesitic, 560, 561—resin of, 549.  
**Allamine**, 528.  
**Alkalies**, organic, 493, 496—vegetable, 493, 494.  
**Alkaloids**, 493.  
**Allantoin**, 487.  
**Alloxan**, 486, 487—hydrated, 490.  
**Alloxatin**, 486, 489—dimorphous, 490.  
**Almonds**, bitter, oil of, 432, 441.  
**Aloes**, 451.  
**Altheine**, 523.  
**Alumina**, 419.\*  
**Amanitine**, 528.  
**Amber**, 443, 452.  
**American oil**, 453.  
**Amide**, 372, 377, 380.  
**Amido chloride of mercury**, 376, 381.  
**Amido subnitrate of mercury**, 381.  
**Amidurets**, 376.  
**Amiduret of benzule**, 442—of hydrogen, 380.  
**Ammeline**, and **ammoline**, 496.  
**Ammonia**, 371, 380, 586\*—benzoate of, 477—cyanate of, 579—humate of, 584—magnesian phosphate of, 582—purpurate of, 490—saliculate of, 480—urate of, 582.  
**Ammoniac**, 451.  
**Ammoniacal gas**, 434.\*  
**Ammonium**, 372, 376, 380, 392\*—oxide of, 455.  
**Amygdaline**, 383.  
**Amyl**, or **amule**, 377, 395—bromide of, 562—ethers, 561—iodide of, 562.  
**Amylic alcohol**, 561.  
**Analysis of blood**, 570—organic, 497—ultimate, 374—of urine, 581.  
**Angustura**, false, 505.  
**Anilina**, or **aniline**, 519, 520.  
**Anhydrous formic acid**, 556.  
**Animal growth**, 582—life, 586—products, 372—substances, 563.  
**Animine**, 496.  
**Anodyne**, **Hoffman's**, 534.  
**Anthracite**, 452.  
**Antiaria**, or **antiarine**, 516, 528.  
**Ants**, 471.  
**Aorta of the ox**, 595.  
**Apirine**, 496.  
**Aqua ammoniac**, 431.\*  
**Arabin**, 399—metamorphic, 399.  
**Aricine**, 504.  
**Arterial fibrine**, 567.  
**Arthanitine**, 527.  
**Artificial camphor**, 439—cold, 539—digestion, 590—fat, 425—fibrin, 567—naphtha, 453—oil of ants, 557—tannin, 466.  
**Asclepine**, 528.  
**Asparagine**, 523.  
**Asparamide**, 523.  
**Asafœtida**, 446, 451.  
**Association of vegetable bodies**, 375.  
**Astringency**, 465.  
**Atropia**, **atropine**, 512, 519.  
**Azardine**, 496.  
**Balsam of Peru**, 383—**Tolu**, 383, 454.  
**Balsams**, 450.  
**Basacigen class**, 376.  
**Base**, 377.  
**Bases**, organic, 493.  
**Basic equivalents**, 455.  
**Basic saliculate of lead**, 480.  
**Basic sulphate of quinia**, 503.  
**Basic water**, 453, 455.  
**Bassorin**, 399, 452.  
**Bdellium resin**, 446.  
**Beans**, 568.  
**Bean**, **tonka**, 481.  
**Beer**, **Bavarian process for**, 597.  
**Beeswax**, 447.  
**Belladonia**, or **belladonnine**, 513.  
**Bengal opium**, 596.  
**Benzamide**, 383, 442.  
**Benzole**, 438.  
**Benzoated oxide of ethyl**, 544.  
**Benzoic ether**, 544.  
**Benzoate of ammonia**, 477.  
**Benzoile**, 377.  
**Benzule**, 377.  
**Benzule**, or **benzyl**, 377, 389—**hydrous** of, 441.  
**Berbina**, 519.  
**Bezoar stones**, 578, 589.  
**Biamido sesquinitrate of mercury**, 381.  
**Biamido sulphate of mercury**, 381.  
**Bibasic acids**, 454, 456.  
**Bichloride of formyl**, 557.  
**Bichlorinated chloride of methyl**, 556.  
**Bichlorinated oxide of methyl**, 556.  
**Bihydramide**, 380.  
**Bihydrate of etherine**, 385.  
**Bihyduret of amide**, 380.  
**Bile**, 576, 587—acids of, 576, 577—**organic** of, 578.  
**Biliary calculi**, 573, 576, 578.  
**Biline**, 577.  
**Biliverdine**, 577.  
**Bioxide of lead**, 486.\*  
**Bisulphide of ethyl**, 546.  
**Bitter almonds**, oil of, or **hyduret of benzule**, 382.  
**Bitumen**, 374, 452.  
**Black elder**, 457.  
**Blanchinine**, 496.  
**Blood**, analysis of, 570—arterial, 567—menstrual, 567—venous, 567, 568.  
**Bone earth**, 574—bones, 573.  
**Brain**, 572.  
**Bread**, leavened, 417.  
**Brewing**, **Liebig on Bavarian process of**, 597.  
**Bromide of acetyl**, 550.  
**Bromide of amyl**, 562—of ethyl, 545.  
**Bromine with formyl**, 557.  
**Bromoforn**, 558.  
**Bromohydrate of bromide of acetyl**, 554.  
**Bromosalicilic acid**, 482.  
**Brucia**, or **brucine**, 505.  
**Bryonia alba**, 525.  
**Bryonine**, 525.

\* See Inorganic Chemistry

\* See Inorganic Chemistry

- Buennine, 538.  
 Butter, 422.  
 Butyrim, 422, 425.  
 Buxine, 496.  
  
 Caffeina, or caffen, 495, 510.  
 Calcium, 372.\*  
 Calculi, 578, 582.  
 Calculus, fusible, 582—mulberry, 582, 588.  
 Camphelene, 440.  
 Camphene, 440.  
 Camphogen, 432.  
 Camphor, artificial, 439.  
 Camphor, 438.  
 Camphor, liquid, 438.  
 Candle, necessity of wick to a, 430.  
 Cane sugar, 402.  
 Canelline, 528.  
 Caoutchouc, 371, 448, 449.  
 Caoutchouchine, 432, 448.  
 Caprin, 422, 425.  
 Caproin, 422, 425.  
 Caramel, 403.  
 Carapine, 496.  
 Carbamide, 381.  
 Carbon, 371.\*  
 Carbon, hydrates of, 373.  
 Carbon, hydruret of, 438.  
 Carbon, perchloride of, 556.  
 Carbonic ether, 543.  
 Carbohydrogen, 562.  
 Carbonic oxide, 375.  
 Carmine, 420.  
 Carnivora, urine of, 581, 590.  
 Cascarilline, 528.  
 Caseine, 568, 569, 411, 418, 564, 567.  
 Caseine, 528.  
 Castor oil, 427.  
 Castine, 496.  
 Catalysis, 599.  
 Catechu mimosa, 469.  
 Cathartine, 525.  
 Cellulose, 410.  
 Centaurine, 528.  
 Cerain, 447.  
 Cerasin, 399.  
 Cerifera, 447.  
 Cerine, 447.  
 Cerosie, 448.  
 Cetene, 398.  
 Cetraria islandica, 525.  
 Cetrarine, 525.  
 Cetule, or Cetyl, 377, 398, 425, 562—chloride of, 398—hydrated oxide of, 398.  
 Charcoal, or carbon, 372.\*  
 Chelidonia, chelidonine, 512.  
 Chelerythrina, 495, 511.  
 Chelerythrine, 495, 511.  
 Chemical type, 378.  
 Chemico-electric reaction, 409.  
 Chicoccine, 496.  
 Chinova bark, 496.  
 Chinova bitter, 526.  
 Chloral, 551.  
 Chlorarsin, 393.  
 Chloride of acetyl, 549, 550.  
 Chloride of calcium, 374, 433.  
 Chloride of ethyl, 545.  
 Chloride of mesityl, 560.  
 Chloride of methyl, 556.  
 Chlorides, 377.\*  
 Chlorides of formyl, 395.  
 Chlorine ether, 549.  
 Chloroform, 558.  
 Chlorohydrate of chloride of formyl, 558.  
 Chlorohydruret, 496, 502, 504.  
 Chlorohydruret of cinchonia, 504.  
 Chlorophyll, 420.  
 Chloroplatinate of chloride of acetyl, 550.  
 Chlorosalicine, 522.  
 Chlorosaliculimide, 482.  
 Chloroxalic ether, 550.  
 Choleate of lead, 577.  
 Choleate of soda, 578.  
 Cholesterine, 570, 573.  
 Chondrine, 572.  
 Chromate of lead, 375.  
 Chyle, 576.  
 Chyme, 576.  
 Cider, 457, 598.  
 Cinchonia, or cinchonine, 494, 504.  
 Cinnamon, oil of, 440.  
 Cinnamule, or cinnamyl, 377.  
 Cinnamyl, hydrate of, 450.  
 Cinnarubrin, 445.  
 Cisampelina, or cisampeline, 495, 518.  
 Clay, 431.  
 Classes of radicals, 377.  
 Cloves, oil of, 440.  
 Coagulated caseine, 568.  
 Coal, mineral, 452.  
 Coal, naphtha, 432.  
 Cocoa, analogous effects as food to those of coffee and tea, 592.  
 Cocoa stearine, 422.  
 Cochineal, 420.  
 Codeia, or codeine, 451, 494, 501, 519.  
 Coffee seeds, 473, 514, 592.  
 Colchicina, or colchicine, 495, 508.  
 Colchicum, 507.  
 Colletine, 528.  
 Colocynthis, 525.  
 Colophonium, colophony, or rosin, 442.  
 Colouring matter, vegetable, or dyes, 419.  
 Columbine, 526.  
 Compound element, 376.  
 Compound radicals, 375, 377.  
 Compounds of proteine, 591.  
 Conina, or coneine, 495, 514.  
 Contraction of arteries, 595.  
 Copaiva, 446.  
 Copal, 446, 453.  
 Copper, carbonate, 403—subacetate, 403.\*  
 Coradalina, or coradaline, 495.  
 Coriarine, 528.  
 Cornine, 528.  
 Corticine, 528.  
 Corydalina, 519.  
 Crotonine, 422, 496.  
 Crystallizable sugars, 400.  
 Cubebs, 527.  
 Cubebine, 527.  
 Cucumis colocynthis, 525.  
 Currants, 462.

\* See Inorganic Chemistry.

\* See Inorganic Chemistry.

Curararia, or curarine, 495.  
 Cyanapine, 496.  
 Cyanarsin, 393.  
 Cyanate of ammonia, 579.  
 Cyanide of methyl, 555.  
 Cyanides, 377.\*  
 Cyanoferrite of quinia, 503.  
 Cyanogen, 372, 377.\*  
 Cyclamine, 527.

Dalleiochin, 504.  
 Daphnine, 496, 528.  
 Datisicine, 528.  
 Datura, 513.  
 Dehydrogenation of ethyl, 547.  
 Delphia, or delphine, 506.  
 Delphinine, 422.  
 Density of essential oils, 434.  
 Derivative radicals, 379.  
 Dextrine, 407, 408.  
 Diabetic urine, 401.  
 Diamond, 372.\*  
 Diastase, 407, 409.  
 Digestion, artificial, 590.  
 Digitaline, 496.  
 Diosmine, 528.  
 Distillation, 373—dry, 382.  
 Dulcamara, 509.  
 Dyeing, 419.  
 Dyes, 419.  
 Dylisine, 577.

Elaldehyde, 549.  
 Elaopten, 431, 438.  
 Elaterium, 525.  
 Emetia, or emetine, 503.  
 Emulsin, 383.  
 Equivalents, basic, 455.  
 Ergot, 401.  
 Ergotine, 526.  
 Erythrophotide of potash, 565.  
 Esenbeckine, 496.  
 Essential oils, 371, 433, 441.  
 Ether, acetic, 542—benzoic, 544—bichlorine, 549—carbonic, 543—chlorine, 549—formic, 543—œnanthic, 544—oxalic, 382, 543—sulphuric, 529—sulphurous, 537.  
 Etherine, 385.  
 Etherole, 533.  
 Ethers, simple, 545—formyl, 556.  
 Ethyl, or ethule, 377, 384, 386—bisulphide of, 546—bromide of, 545—chloride of, 545—compounds of, 386—cyanide of, 546—formiated oxide of, 543—hydrated oxide of, 544—oxide, citrate of, 544—œnanthated oxide of, 544—iodide of, 545—selenide of, 546—sulphide of, 545—sulphydrate of the sulphide of, 546—tartrate of the oxide of, 544—telluride of, 546.  
 Eupatorine, 496.  
 Euphorbine, 496.  
 Euphorbium, 451.  
 Excrements, human, 578.  
 Exostosis, 574.

21—of animals, 592.  
 ers, 572.  
 t, 399—with potash, 407—with s, 407.  
 d, 436, 439.  
 entable matter of diabetes, 55.  
 entation, 596, 598, 604.  
 , 411, 415, 567—arterial, 567.  
 Fixed oils, 426, 429.  
 Flax, 409.  
 Fluoride of calcium, 574.  
 Fluorides, 377.  
 Fluorine, 372.  
 Food in cold climates, 587—in warm climates, 587—of vegetables, 563.  
 Formiated oxide of ethyl, 543—of methyl, 557.  
 Formic ether, 543.  
 Formulæ of resins, 446.  
 Formyl, or formule, 377, 395, 557.  
 Fossil copal, 446.  
 Fraxinine, 528.  
 Fumarine, 496.

Galbanum, 451.  
 Gamboge, 451.  
 Gas, chlorohydric acid, 530.  
 Gastric juice, 576.  
 Gaultheria, 479, 482, 521.  
 Gelatine, 571, 591.  
 Gelatinous tissue, 571.  
 Gentianine, 524.  
 Geraniine, 528.  
 Glass bulbs, analysis of volatile liquid by, 375.  
 Glaucine, 496.  
 Glauco-picrine, 496.  
 Gliadine, 412.  
 Globuline, 549, 570.  
 Glue, 412. See *Gelatine*.  
 Gluten, 409, 411, 412.  
 Glycerine, 397.  
 Glyceryl, or glycerule, 377, 396, 562.  
 Graminivorous animals, 415.  
 Granatine, 528.  
 Grape sugar, 403, 404.  
 Gravel, 588.  
 Grey part of brain, 573.  
 Guacine, 528.  
 Guaiacine, 464, 526.  
 Guaiacum, 526.  
 Guano, 485.  
 Guarana, 510.  
 Gum, 373, 399, 586—arabic, 399—class, 44—senegal, 399—tragacanth, 399.  
 Gypsum, 583.

Hair, 566.  
 Halogen bodies, 382.\*  
 Harnalina, 519.  
 Heat by arterial contraction, Wiggers hypothesis, 595.  
 Heavy oil of wine, 476.

\* See Inorganic Chemistry.

\* See Inorganic Chemistry.

na, 518.  
 osin, 594.  
 fibres of, 409, 410.  
 idine, 528.  
 rates, 478.  
 n's anodyne, 534.  
 566, 572.  
 comb, 446.  
 e of ammonia, 584.  
 i, 584.  
 e of etherine, 385—of potash, 374—  
 da, 374.  
 ed oxide of acetyl, 547—of amyl,  
 561—of ethyl, 385, 534—of formyl,  
 —of methyl, 394, 552.  
 ret of amide, 380— of benzule, 382,  
 —of cinnamyl, 383.  
 etate of ammonia, 548.  
 etous acid, 390.  
 itrate of oxide of methyl, 554.  
 itrous ether, 539.  
 etical radical, 384.  
 ine, 528.  
 528.  
 torine, 527.  
 iodide of mesityl, 560.  
 ties of rain water, 583.  
 ice of heat, 373.  
 sugar, 405.  
 le, or coagulated fibrine, 567.  
 of amyl, 562—of ethyl, 545—of me-  
 555.  
 i, 377—iodides, alkaline, 519.  
 372.\*  
 uanha, 508.  
 72, 595.  
 ca cetraria, 525.  
 ss, 571.  
 lack, 574.  
 ina, or jamaicane, 496, 518.  
 i, or jervine, 508, 519.  
 gastric, 576, 591—pancreatic, 576.  
 ile, or kacadyl, 377, 393—chloride  
 3—cyanide of, 393—hydrated tri-  
 of, 393—oxide of, 393—sulphide  
 3.  
 te, 432, 440, 441.  
 404, 574.  
 arium, 526.  
 ine, 526.  
 419.  
 ine, 528.  
 substitution, 379.  
 , 568.  
 e, 565.  
 anges during, 582.  
 polarized, 405—polarization of, by  
 ine, 408—by starch, 408—by su-  
 402.  
 , 373, 407, 408, 409, 452.  
 ulphuric acid, 410.  
 ie, 559.  
 rine, 528.

Lilacine, 528.  
 Lime, oxalate of, 582.  
 Lime-water, 374.  
 Liquid camphor, 438.  
 Liquorice sugar, 405.  
 Liquids, 375.  
 Liriodendrine, 528.  
 Lobelia inflata, 515.  
 Lobelina, 515.  
 Lobeline, 515.  
 Lupuline, 526.  
 Lute, chemical, 448.  
 Lymph, 579.  
 Maceration, 433.  
 Magnesia, 497.  
 Magnesium, 372.  
 Maize, 414.  
 Malt wort, 409.  
 Manna, 406.  
 Manna sugar, 460.  
 Mannite, 406, 460.  
 Manures, 585.  
 Margarine, 422, 425.  
 Meadow saffron, 507.  
 Meconin, 451, 452.  
 Meconine, 527.  
 Meconium, 588.  
 Melamine, 520.  
 Melampyrine, 528.  
 Mellon, 377, 379.  
 Membrane, arterial composition of, 572.  
 Menispermia, 519.  
 Menispermine, 496.  
 Menthén, 459.  
 Menyanthine, 528.  
 Mercaptan, 546.  
 Mesite, 559.  
 Mesiten, 559.  
 Mesityl, or mesitylene, 377, 560.  
 Metacetone, 391.  
 Metaldehyde, 549.  
 Methal, 560.  
 Methyl, or methule, 377, 394, 471—com-  
 pounds of, 556—cyanide of, 555—ethers,  
 551.  
 Methylal, 557.  
 Methylic alcohol, 552—ether, 551—mer-  
 captan, 555.  
 Methylous hyponitrous ether, 554.  
 Milk, 404, 457, 460, 574.  
 Mineral coal, 374, 452.  
 Mineral naphtha, 432.  
 Modifications of proteins, 564.  
 Molasses, 401.  
 Molybdenum, peculiar insolubility of its  
 acetate, 459.  
 Momordica elaterium, 525.  
 Monobasic acids, 454, 455—salts, 456.  
 Monkhood, 512.  
 Mordants, 419.  
 Morphia, or morphine, 498.  
 Mould, 585.  
 Mucus, 579.  
 Mudarine, 525.  
 Mulberry calculus, 582, 588.  
 Murexide, 490, 491.

\* See Inorganic Chemistry.

\* See Inorganic Chemistry.

Mariate of morphia, 500.  
Muscular fibre, 570—tissue, 570.  
Mushrooms, 401—sugar of, 405.  
Myrica angustifolia, 447.  
Myricine, 447.  
Myristicine, 422.  
Myrrh, 451.  
Myrtleberries, 447.  
  
Naphtha, 452—artificial, 453.  
Naphthene, 452.  
Naphthol, 452.  
Narceia, 451, 501.  
Narcotine, 528.  
Narcotina, or narcotine, 451, 501.  
Nervous matter, 572.  
Neutral organic principles, 521.  
Neutral sulphated oxide of methyl, 553.  
Nicotina, or nicotine, 515, 520.  
Night shade, 509.  
Night soil, cause of efficacy as manure, 586.  
Nitrated hydruret of cinnamyl, 383.  
Nitrated oxide of methyl, 553.  
Nitrogen, 372.\*  
Nutrition and growth, 582.  
  
Oak galls, 465.  
Oats, gluten in, 414.  
Odorine, 496.  
CEnanthated oxide of ethyl, 544.  
CEnanthic ether, 544.  
Oil of amber, 453—of ants, artificial, 557—  
of anise, 439—of asarum, 439—of bella-  
donna, 428—of bitter almond, 384, 432  
—of black mustard, 432, 435—of cloves,  
440—of cinnamon, 383, 440—of cubebs,  
439—of elecampane, 439—of fennel, 439  
—of hops, 435—of horse-radish, 435—  
of mustard, 517—of parsley, 439—of  
peppermint, 439—of potato spirit, 473—  
of olives, 423—of onions, 435—of rose,  
439—of sassafras, 445—of spirea ulma-  
ria, 384, 483—of sunflower, 428—of tur-  
pentine, 439—of water-pepper, 435—of  
wine, 533—of wine, heavy, 533.  
Oils and fat, 421.  
Oils, fixed, 421, 426.  
Ole-essence, 431.  
Olefiant gas, 549.\*  
Olein, 422, 425.  
Olivile, 528.  
Olivine, 528.  
Opium, 451.  
Organic alkalies, 498—hydrates, 373—sub-  
stances, 371—tissues, 372.  
Osmazome, 570.  
Oxacids, 464.\*  
Oxalate of ammonia, 381.  
Oxalated oxide of ethyl, 543—oxide of  
methyl, 555.  
Oxalic ether, 543.  
Oxalurate of ammonia, 490.  
Oxamide, 381, 382.  
Ox bile, 588.  
Oxide, carbonic, 381—of copper, 374—

acetic — — yl, 385—of glycer-  
ol, or mesityl, 550—of methyl, 551.  
Oxides, 377.  
Oxidized iron, use of, as a mordant, 48.  
Oxychloride of acetal, 550.  
Oxygen, 371.\*  
Oxygen, volatile oils containing, 438.  
Oxysulphide of acetal, 550.  
  
Palmatine, 422.  
Palm oil, 422.  
Papin's digester, 505.  
Paraffin, 452.  
Paramenispermene, 496.  
Paramorphia, 451, 500.  
Peas, legumen or vegetable cassia is,  
414, 568.  
Peat, 585.  
Pepsine, 575.  
Perbromide of formyl, 557.  
Perchlorate of oxide of ethyl, 541.  
Perchloric ether, 541.  
Perchloride of carbon, 556.  
Perchloride of formyl, 557, 558.  
Perchlorinated oxide of methyl, 554.  
Periodide of formyl, 557.  
Phenomena of fermentation, 600, 602, 603.  
Phloridzeine and phloridzine, 523.  
l asphate of ammonia, 589—of lime, 45,  
374, 582.  
l asphorus, 372, 415.  
l nillyrine, 528.  
Picrolichenine, 525.  
Pieromel, 578.  
l rotoxia, or picrotoxine, 516, 519.  
l mentum nigrum, 572.  
l er cubeba, 527.  
l ayine, 496.  
Platina sponge and black, 471, 600.\*  
Plumbagine, 526.  
Polarized light, 408.\*  
Polygala senega, 526.  
Poplar, 384.  
Poppy, 519.  
Populine, 528.  
Potash, 497.  
Potassium, 372, 385.\*  
Primuline, 528.  
Principles devoid of nitrogen, 524.  
Proof spirit, best solvent for gum resins,  
451.  
Proteine, 564—compounds of, 321.  
Protide, 565.  
Protochloride of formyl, 557.  
Pseudomorphia, 451, 500.  
Pteleyle, 560—chloride of, 560—nitrated  
oxide of, 560.  
Pus, 579.  
Putrefactive fermentation, 604.  
Pyretine resins, 443.  
Pyrethrine, 525.  
Pyrogenic acids, 455—oils, 443—resins,  
443.  
Pyroxylic spirit, 394, 552.  
Quadrooxide of nitrogen, 490.

\* See Inorganic Chemistry.

\* See Inorganic Chemistry.

6.  
meadow, 384.  
inine, 501, 519.  
c sulphate of, 502—neutral  
f, 503—phosphate of, 503—  
3, 504.  
rk, 496.

mpound, primitive, deriva-

emical, 520.  
red cause of its efficacy, 568.  
30.

-saponification of, 444—table

lehyde, 549—benzoin, 446—  
445—copal, 446—guaiac, 446

446.

28.

, 443.

425.

ne, 425.

eat dough, 317.

rops, 586.

3.

in, 414.

7, 519.

ermentation, 597.

521, 522.

80.

potash, 480.

licule, 377, 384.

uret of, 521.

22

ids, 575.

phia, 500.

l, 544.

ger, 457.

2, 496.

24.

6.

445.

420.

451.

ima, 525.

5.

8.

, 528.

74.

oducts, 372.

, 524.

153.

26.

, 528.

he blood, 570.

acetate, 460.

ret of nitrogen, 377.

of iron, 470.

state of lead, 460.

ls, 428.

Silicon, 371, 372.\*

Silver, saliculate of, 481.

Simple ethers, 545.

Sinapoline, 435.

Skins of animals, 571.

Smilacine, 526.

Smilax sarsaparilla, 526.

Soda, choleate of, 578.

Soda, hyponitrite of, 539—nitrate of, 586.

Soil for potatoes, 585.

Solanaceæ, 519.

Solania, or salanine, 509.

Solvent of oils, 433, 434.

Spartine, 528.

Spermaceti, 398, 444.

Spigeline, 528.

Spirea ulmaria, 479.

Spirit of Mindererus, 460.

Staphisia, 519.

Starch, 373, 406, 586.

Starkey's soap, 434.

Stavesacre, 506.

Stearate of potash, 425.

Stearine, 422.

Stearopten, 431, 438, 481.

Stones, bezoar, 578, 589.

Straw, 410.

Strychnine, 505.

Strychnos, nux vomica, 505.

Suavin, 401.

Subordinate radicals, 377.

Substantive dyes, 419.

Suet, 444.

Sugar, 373, 399, 401—anhydrous grape,  
403—of bile, 578—of the cane, 402—  
diabetic, 402—grape, 402—liquorice, 402  
—of manna, 402—of milk, 402, 404—  
mushroom, 402, 405—of lead, 460—un-  
fermentable, 405, 406—acts as an acid,  
403.

Sugars, 400.

Sulpharsin, 393.

Sulphate of ether, 475.

Sulphate of ether and water, 474.

Sulphated oxide of elayl, 475.

Sulphate of indigo, 420.

Sulphide of ethyl, 545—of methyl, 555.

Sulphocyanide of potassium, 575.

Sulphur, 372, 415.

Sulphuric ether, 529.

Sulphurous ether, 537.

Summer strained oil, 422.

Surinamina, or surinamine, 496, 518.

Sweat, 457.

Sweet spirits of nitre, 540.

Symbols, 377.

Synaptase, 383.

Synthesis, 372.

Syrups, 400.

Table of alkalies, 494, 495.

Table of oxygen oils, 436.

Tallow, 426, 444.

Tanacetine, 528.

Tanghinine, 527.

Tannin, artificial, 466.

- Tantalum**, 466.  
**Tapioca**, 406.  
**Taraxacine**, 523.  
**Tartar**, cream of, 462.  
**Tartarized iron**, 462.  
**Tartrate of potash and soda**, 462.  
**Tar water**, 440, 592.  
**Taurine**, 577.  
**Tawed leather**, 571.  
**Tea**, 510.  
**Teeth**, 574, 592.  
**Terebene**, 440.  
**Tests of morphia**, 500, 520.  
**Thebaine**, or thebaine, 500, 519.  
**Theine**, 510, 592.  
**Theobromia**, 519.  
**Thiosinamina**, 517.  
**Titanium**, 466.  
**Tobacco**, oil of, 428.  
**Tonka bean**, 481.  
**Torrefaction**, 407.  
**Tremelline**, 528.  
**Trioxide of acetyl**, 457.  
**Tungsten**, peculiar insolubility of its acetate, 459.  
**Turpentine**, oil of, 433.  
  
**Ulmia**, 452.  
**Ultimate analysis**, 371.  
**Uncrystallizable sugars**, 401.  
**Uramile**, 489, 490.  
**Urate of ammonia**, 485, 582.  
**Urate of potash**, 485.  
**Urea**, 579.  
**Urea**, nitrate of, 580.  
**Uril**, 484, 487.  
**Urinary calculi**, 582.  
**Urine**, 457, 492, 579—acid and alkaline, 581—of birds, 581—carnivora, 581—of the herbivora, 581—of serpents, 581.  
  
**Valeryl**, 473.  
**Varnish**, 428.  
**Vegetable acids**, 374—alkalies, 493.  
**Vegetable albumen**, 413—caseine, 411, 415, 418—elements, 413—fibrous growth, 582—life, 586—substances  
**Vegeto-alkalies**, 493.  
**Vegeto-animal ferment**, 597.  
**Vegeto-animal substances**, 411.  
**Veratria**, 507, 519.  
**Veratrine**, 507.  
**Veratrum sabadilla**, 507.  
**Venous blood**, 595—fibrine, 56.  
**Vinegar**, 457.  
**Vinous fermentation**, 597.  
**Violine**, 496.  
**Viscous fermentation**, 598.  
**Volatile bases**, 519—oils, 429, formula of, 436.  
  
**Watch work**, oil for, 423.  
**Water**, 373, 374—rain, contains  
**Waxes**, 446, 447, 592.  
**Waves**, abating influence of oil  
**Wax**, 446, 447, 592.  
**Wheat**, 413, 416.  
**White hellebore**, 507.  
**Will and Varentrap's process** for  
**Willow**, salicyl or salicin, from  
the, 384.  
**Winter strained oil**, 422.  
**Wood**, 409—distillation of, 457.  
**Wood spirit**, 395, 552.  
**Wool**, dyeing of, 420.  
**Wort**, 401, 409, 597.  
  
**Xanthopicroine**, 525.  
**Xanthic oxide**, 582.  
**Xylit**, 559.  
**Xylite**, 559.  
**Xylite naphtha**, 560.  
**Xylite oil**, 560.  
  
**Yellow wax**, 447.  
  
**Zedourine**, 528.  
**Zimome**, 412.

\* See Inorganic Chemistry



## EMENDATIONS

### *recting the Isomeric Acids of Phosphorus, the Atomic Weight of Silicon, and Composition of Silica.*

will be perceived by the readers of that portion of this Compendium which treats of "acids relatively to the proportion of base required for saturation" (5181), that a new doctrine has been advanced on that subject. Consistently a very important modification has been made with respect to the three previously supposed isomorphates of phosphoric acid (1153). They are inferred to differ from each other *only* in the proportions of water, or other base which they require severally for their saturation; so that there is a monobasic, a bibasic, and tribasic phosphoric acid (5184). When in the late heretofore designated as *free*, they are considered as containing three phosphates of water. This assumed constitution of the isomeric acids has been represented by Dr. Kane, and other able chemists, as affording strong evidence of the existence of bound radicals in certain salts. Hence having, in arguing against the existence of such radicals, adverted to the constitution of the different phosphates of water,\* I deem it expedient to give, in the language of Dr. Kane,† an account of the acids of phosphorus to which reference is made, and of their habitudes with basic water and other

Phosphoric acid has a great affinity for water, combining with it almost exactly. It may form three distinct compounds, *phosphates of water*, the constitution of which is as follows:—

Monobasic phosphate of water,	- -	$\text{PO}^5 + \text{HO}.$
Bibasic phosphate of water,	- -	$\text{PO}^5 + 2\text{HO}.$
Tribasic phosphate of water,	- -	$\text{PO}^5 + 3\text{HO}.$

This relation was first established by the researches of Graham. Phosphoric acid unites not only with water in these three proportions, but each of them is a type series of salts, which the phosphoric acid is capable of forming. Thus, there is a class of *monobasic phosphates*, another class of *bibasic phosphates*, and a third, which is the most common, of *tribasic phosphates*; the water contained in the phosphates of phosphorus being replaced to a greater or less extent, by means of equivalent proportions of metallic oxides.

A solution of phosphoric acid in water, may contain any one of the three phosphates of water that have been described, and when neutralized by bases may hence form totally different salts. The properties of a solution of phosphoric acid may, therefore, be totally different according to the manner in which it had been prepared, since this acid was at one time ranked as a remarkable instance of *isomerism*; and Graham has beautifully shown, that the difference of properties is only the result of the existence of the different states of combination in which the phosphoric acid may exist. It will consequently be necessary to study separately the properties of the three compounds of phosphoric acid with water.

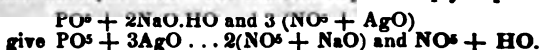
*Monobasic Phosphate of Water.*—A solution of this body reacts powerfully acid, it coagulates albumen (white of egg) in white curds; when neutralized by a base, it forms salts which contain but one atom of base, their formula being  $\text{PO}^5 + \text{RO}$ ; and the double salt of it produces in solutions of silver, a white, soft, precipitate,  $\text{PO}^5 +$

an effort to refute the arguments in favour of the existence in amphoteric salts of a compound radical like cyanogen. See Emendations, page 485.

AgO. This is the least stable of the phosphates of water, it gradually passes into the other forms, particularly when its solution is boiled.

*Bibasic Phosphate of Water.*—This form of the acid may be prepared by decomposing bibasic phosphate of lead by sulphuretted hydrogen. It is characterized by combining always with two equivalents of base, forming salts, whose formula is  $\text{PO}^3 + 2\text{RO}$ ; its salts give, with nitrate of silver, a white precipitate,  $\text{PO}^3 + 2\text{AgO}$ , which is not pasty like the monobasic phosphate. The salts of this acid may contain only one equivalent of fixed base, the other being water, and may hence, at first sight, appear to be constituted like the monobasic salts; the basic water is, however, easily known to be present, by its not being expelled by a moderate heat, with the water of crystallization, but requiring a temperature approaching to ignition for its expulsion.

*Tribasic Phosphate of Water.*—This is the form of phosphoric acid which represents the class of salts most generally known; it is characterized by not precipitating albumen, and by combining with three equivalents of base when fully neutralized. In the majority of cases of the three equivalents of base, one is water; thus the common phosphate of soda is a tribasic phosphate, its formula being  $(\text{PO}^3 + 2\text{NaO.HO}) + 24\text{Aq}$ ; when moderately heated, or even by long exposure to dry air, it loses the  $24\text{Aq}$ , but it requires to be melted at a red heat, in order to drive off the twenty-fourth atom of water; and if this be done, on redissolving the fused mass in water, it crystallizes in a totally different form, and is found to have been changed into bibasic phosphate of soda, the formula of which is  $(\text{PO}^3 + 2\text{NaO}) + 10\text{Aq}$ . The difference is remarkably shown by the action of these salts on a solution of silver; common phosphate of soda precipitates nitrate of silver of a canary yellow, and the solution becomes acid; one equivalent of tribasic phosphate of soda, decomposing three equivalents of nitrate of silver, producing one equivalent of tribasic phosphate of silver, two of nitrate of soda, and one of nitrate of water; this last being liquid nitric acid, of course renders the liquor acid. The reaction may be simply expressed



If on the other hand, bibasic phosphate of soda be used, the liquor remains neutral, for  $\text{PO}^3 + 2\text{NaO}$  and  $2(\text{NO}^3 + \text{AgO})$  give  $\text{PO}^3 + 2\text{AgO}$  and  $2(\text{NO}^3 + \text{NaO})$ .

In the tribasic phosphates, it frequently occurs, that there shall be but one equivalent of fixed base, the other two being water; such salts have frequently an acid reaction, and were formerly called biphosphates. Thus one tribasic phosphate of soda is  $\text{PO}^3 + \text{NaO.2HO}$ ; the biphosphate of ammonia is tribasic, its formula being  $\text{PO}^3 + \text{NH.O.2HO}$ .

These salts of phosphoric acid were originally designated by Graham, metaphosphates, pyrophosphates, and common phosphates."

It may be proper to add that the opinion of Professor Rose respecting the identity in composition of the different kinds of phosphuretted hydrogen(1166), of which one only is spontaneously inflammable, has been confirmed. According to analysis, either consists of an atom, or volume, of phosphorus and three atoms, or six volumes, of hydrogen, the whole aggregate being condensed into four.

Their unlikeness, as respects spontaneous inflammability, is ascribed to the presence of impurities which tend either to promote or to retard reaction with atmospheric oxygen.

### *Atomic Weight of Silicon and Composition of its Oxide.*

In this Compendium (1361), the equivalent of silicon is stated to be 8, and that taking one atom of oxygen to form silicic acid, the equivalent of this compound, known also as silex or silica, is 16. But latterly it has been inferred that the equivalent of silicon is 22.22. And that to form silicic acid it takes 3 atoms of oxygen = 24.

Consistently the equivalent of silicic acid is 46.22

©

A

BRIEF EXPOSITION

OF

THE SCIENCE

OF

MECHANICAL ELECTRICITY,

OR

ELECTRICITY PROPER;

SUBSIDIARY TO THE

COURSE OF CHEMICAL INSTRUCTION

IN THE

UNIVERSITY OF PENNSYLVANIA:

WITH ENGRAVINGS AND DESCRIPTIONS OF THE APPARATUS EMPLOYED.

BY

ROBERT HARE, M.D.

PROFESSOR OF CHEMISTRY.



PHILADELPHIA:

J. G. AUNER, No. 343 MARKET STREET.

John C. Clark, Printer.

1840.



## PREFACE.

---

AT the period when the medical school, in which I have the honour to hold the chemical professorship, was founded, the science of chemistry extended to little more than a knowledge of some acids, alkalies, earths, and salts, of which the most important ingredients were unknown. Even the composition of atmospheric air, and of water, was not understood; the existence of the all-important elements, oxygen, hydrogen, and nitrogen, &c. having been detected. The subsequent discovery by Dr. Black, of the latent agency of heat, was the first step in a department of our science, which at this period occupies, in a course of chemical lectures, a large portion of the time. The discovery of the same great chemist that atmospheric air was not to be considered as a fluid *sui generis*—that there might be more than one kind of æriform matter; by leading to a knowledge of the gases, added another topic, which, in all its bearings, practical and theoretical, may be considered as no less entitled to attention, than the phenomena of heat. The invention of the Voltaic pile, and the employment of its wonderful powers in effecting chemical decomposition, besides leading to a knowledge of many chemical facts and agents, connected either in theory or practice, opened the whole science of electricity, whether galvanic or mechanical, with chemistry.

To these topics have latterly been added the electromagnetic properties of matter; which by their association with electricity, with a power of chemical decomposition, and of giving shocks to the animal frame, force themselves upon the attention of the chemist and physiologist.

Both the theory and nomenclature of our science, are at present grounded upon the electrical habitudes of chemical agents. Under these circumstances, a knowledge of galvanic and mechanical electricity is of fundamental importance; and to impart this knowledge, where it has not to a sufficient extent been made part of the student's previous education, should be a primary object.

These impressions are sanctioned by the practice of the most distinguished writers of elementary works upon chemistry, in each of which I believe a brief treatise, on the electrical sciences, is made to precede that upon chemistry proper.

## PREFACE.

It is in the school, by the fact, that all of  
as a remedy. The question who  
will be presented to the practitioner,  
to of their nature, or the means  
of their influence on the vital functions  
y.

## CONTENTS.

---

	Page
<b>A Brief Account of the Origin and Progress of Electricity</b>	1
<i>Electricity experimentally illustrated</i>	4
<i>Order pursued in the experimental illustration of Electricity</i>	5
<i>Generic description of the Electrical Machine</i>	5
Electrical machine with a plate four feet in diameter	6
Engraving and description of an electrical cylindrical machine	6
Description of an electrical plate machine	7
<i>Of the usual means of producing Electricity</i>	8
Experimental illustration	9
<i>Of the communication of Electricity</i>	9
Experimental proofs that electricity does not pass from one part of an electric to another, through or by means of the electric	9
Peale's experiment	9
Modification of Peale's experiment	11
Additional illustration	11
Experimental proofs that metals, charcoal, moisture, flax, or hemp, are conductors of electricity, and that sulphur, resins, glass, silk, and wool, are non-conductors	12
<i>Of different kinds of Electricity</i>	13
Description of Bennet's gold leaf electrometer	14
Experimental illustrations	14
<i>Of Electric Poles.—Of Electric Circuits</i>	14
<i>Means of accumulating Electricity</i>	16
Experimental illustrations	17
Coated pane	17
Of the Leyden jar	18
Of the common discharger	18
A charge is imparted, equally well, by the contact or communication of either coating with either conductor	19
Experimental proofs that the different surfaces of a charged electric are oppositely electrified	20
Chime of bells	20
Metallic coatings of use in conveying the charge—but it does not reside in them	21
Pane with moveable coatings	21

	Page
Glass vessel so situated that water is made to perform the same office as metallic coatings in the Leyden phial; illustrating the original experiment of Cuneus and Mushenbroeck	22
Experimental demonstration that the charge of a Leyden jar does not reside in the coatings	23
<i>Of Electrical Batteries</i>	23
Of an electrical battery of 32 jars, each 13 inches in height, and 5 inches in diameter	24
Description of Henley's universal discharger	24
Battery discharger for deflagrating wires	25
<i>Of Electrical excitement by induction</i>	25
Apparatus for the illustration of electrical induction	26
New apparatus for the illustration of electrical induction	27
Exposition of the difference between induction and conduction	29
Dynamic electrical induction	29
<i>Means of detecting or measuring Electricity</i>	29
Description of the condensing electrometer	30
Description of Henley's quadrant electrometer	31
Description of the single leaf electrometer	31
Of Coulomb's electrometer	32
Of Cuthbertson's balance electrometer	32
<i>Of the effects of Electricity</i>	34
<i>Of Electrical Attraction</i>	34
Revolution of a sun, planet, and satellite	34
Electrical tree	35
Electrical hail	36
<i>Electric Light illustrated</i>	36
Experimental illustration of the efflux and afflux of the electric fluid during the charging and discharging of coated surfaces as rendered evident by means of a discontinuous coating of metallic filings	36
Long zigzag or erratic spark, contrasted with the short straight spark	37
Of the electrical brush	38
Globe, illuminated panes, and tubes	41
Illuminated columns	42
Carreaux étincelantes, (sparkling panes)	45
Illuminated eggs	47
<i>Electric Light in vacuo</i>	44
Aurora borealis.—Shooting stars	44
<i>Electrical Ignition experimentally illustrated</i>	45
Ignition of cotton by the electric spark	45
Inflammation of ether by the electric spark	45
Ignition of inflammable matter by the electric spark.—Ignition of hydrogen with oxygen	46
<i>Of mitigating the effects of Electricity</i>	46
Of the proper mode of constructing, and putting up, lightning rods	46
King's improvement in putting up lightning rods.—Expedient suggested by the author	46
Experimental illustration	46



# CONTENTS.

vii

Page

<i>Additional means of producing Electricity</i>	-	-	-	49
Of the electrophorus.—Of electricity evolved by the friction of caoutchouc, by pressure, by chemical changes, and by the contact of heterogeneous metals	-	-	-	49
Of the electrophorus	-	-	-	49
Evolution of electricity from caoutchouc by friction	-	-	-	50
Of electricity evolved by pressure	-	-	-	50
Evolution of electricity from caoutchouc by pressure	-	-	-	50
<i>Theoretical Explanation of Electrical Phenomena</i>	-	-	-	50
Of the theory of two fluids	-	-	-	50
Additional remarks explanatory of Franklin's hypothesis	-	-	-	52
Rationale of electric light and ignition	-	-	-	53
<i>Means of electrifying a patient with sparks</i>	-	-	-	53
<i>Apparatus for electrifying a patient by shocks</i>	-	-	-	54



## A BRIEF ACCOUNT

*Of the Origin of the Science of Electricity Proper; and of the Progress which it made prior to the time of Galvani.*

1. An attractive power is acquired by resins, sulphur, glass, and a variety of other substances, when rubbed; and if the masses, thus excited, be sufficiently large, the phenomena of light, of mechanical concussion, and ignition, may result, and even a feeble imitation of thunder and lightning.

2. As it was in amber, in Greek called *Electron*, that the attractive power, arising from friction, was first observed, the principle to which it was ascribed was called electricity, and all substances, in which it could be produced, electrics.

3. We are informed that Thales of Miletus, who flourished six hundred years before Christ, was so much struck with his effect of the friction of amber, as to imagine that it might be endowed with animation. Subsequently, it was ascertained that the attractive power, which had been observed in amber, after being rubbed, might be produced, by the same means, in other resinous substances, and in the tourmaline, or lyncurium, as it was then called, by exposure to heat.

4. No further progress was effected in electrical knowledge until the seventeenth century, when, after considerable additions had been made to the catalogue of electrics by Gilbert and Boyle, Otho Guericke discovered that light and sound might result from electric excitement. His observations were made by means of a globe of sulphur, cast in a glass vessel which was fractured to extricate the casting. Little was it suspected by the ingenious operator, that the glass globe, thus broken, would have answered better for the purpose in view, than the globe of sulphur in the moulding of which it was sacrificed.

5. The discovery of the usefulness of glass as a mean of producing electricity, appears to have been made by

Hawkesbee, who wrote in 1709. To Grey, who followed Hawkesbee, we owe the remark that the electrical excitement of glass and other electrics was communicable to other bodies when insulated, not only by direct contact, but by wires or threads of great length; and by this electrician, in conjunction with another named Wheeler, it was first observed that this property of conducting the electric virtue, while belonging to flax or hemp, did not belong to silk; also, that, by the class of bodies in which electricity can be excited, it cannot be conducted; whilst in those by which it may be conducted, it cannot be excited. Thus were two classes of bodies distinguished: one as electrics, or non-conductors; the other as non-electrics, or conductors.

6. It was ascertained, however, that a conductor, if supported by a non-conductor, might receive the electric virtue from an excited electric. A conductor, so supported, was said to be *insulated*.

7. Du Faye soon after ascertained the important truth that there are two kinds of electrical excitement. One of these, being observed in glass, was called *vitreous*; and the other, resinous, because observed in resins. By the communication of either species of excitement, light bodies were made to separate from each other; but the bodies excited by means of resins were attracted by such as were excited by means of glass; and when these opposite excitements were made, in due proportion in different insulated conductors, on bringing the conductors together, a neutralization, and of course an apparent annihilation, of the electricity in both was the consequence.

8. The means of collecting the electric fluid were soon after much improved in Germany; where sparks sufficient to kill birds, and ignite spirits and other inflammable matter were produced by the joint influence of several globes simultaneously excited.

9. In the year 1746, the Leyden phial was invented. Cuneus and Mushenbrœck, attempting to charge the water contained in a phial with electricity, a shock was experienced by Cuneus, who happened to touch the conductor with one hand, while grasping the phial with the other.

10. This phenomenon was soon after explained by Franklin. He had ascertained that, whenever either kind of electricity is communicated by friction to one surface, the other

kind will be created in that by means of which the friction is effected, provided it be insulated.

11. When a glass is rubbed by the hand, it takes electricity from the hand, and from the person to whom it belongs. If standing on a non-conductor, the person will be electrified, at the same time that the glass which he rubs may, by due proximity, excite another body; but, then, the electricity of the person who rubs the tube, and that of any body to which the tube may electrify are of opposite kinds; the former being the resinous, the latter the vitreous electricity of Du Faye. A stick of resin would cause the opposite result, producing vitreous electricity in the person rubbing it, and resinous in a body touching the resin, subsequently to its exposure to friction.

12. These phenomena were thus accounted for by Franklin. Some bodies by friction (glass for instance) acquire additional power to hold the electric fluid, and hence draw it from the conducting body rubbing them, and give up the excess to any adjoining conductor, when the friction ceases. Resins, on the other hand, have their capacity for the electric fluid lessened by rubbing, and hence, while subjected to this process, give it out to the rubber, and afterwards draw on any adjoining body to supply their deficiency. Glass and resin, therefore, produce both kinds of electricity, which are merely the result of an accumulation, or deficiency, in an insulated body, of a fluid which pervades the creation. A conductor, charged in either way, will produce an electrical current when presented to other bodies in connexion with the earth. In the one case, electricity will flow into the conductor; in the other case, it will flow out of it.

13. Franklin, also, discovered that, when an electrical stream is directed into a phial, situated like that of Cuneus, there is, at the same time, a stream proceeding from the outside; so that, in proportion as one surface gains, the other loses; and, accordingly, in a charged phial, one surface will be found vitreously, or redundantly, excited, the other, resinously, or deficiently; and a light body, after touching either surface, will be repelled by it, and attracted by the other.

14. He inferred that there was only one electric fluid, to different states of which, the names of vitreous and resi-

nous electricity, had been erroneously applied. The latter he called negative, the former positive electricity.

15. Franklin afterwards identified lightning with electricity, by drawing this fluid from the clouds by means of a kite; availing himself of a contrivance, which had previously been appropriated to juvenile recreation, to make a most sublime and useful discovery.

OF  
MECHANICAL ELECTRICITY,  
OR  
ELECTRICITY PROPER.\*

---

ORDER TO BE PURSUED IN TREATING OF ELECTRICITY.

DESCRIPTION OF ELECTRICAL MACHINES.—USUAL MEANS OF PRODUCING ELECTRICITY.—COMMUNICATION OF ELECTRICITY.—DIFFERENT KINDS OF ELECTRICITY.—MEANS OF ACCUMULATING ELECTRICITY.—MEANS OF DETECTING ELECTRICITY.—EFFECTS OF ELECTRICITY.—ADDITIONAL MEANS OF PRODUCING ELECTRICITY.—THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.—MEANS OF ELECTRIFYING PATIENTS EITHER BY SPARKS OR BY SHOCKS.

GENERIC DESCRIPTION OF THE ELECTRICAL MACHINE.

16. I am unacquainted with any apparatus, designated as an electrical machine, which does not consist of an electric, so situated as to be conveniently subjected to a friction calculated to produce electric excitement, one or more collectors, attached to a prime conductor properly insulated, and one or more cushions, for rubbing the electric. The cushions, in the more perfect forms of the machine, are associated with another insulated conductor.

17. Experience has shown that, of all the electrics, glass is the best for the construction of electrical machines; and as of all the possible forms, only two are much in use,

\* It seems to be impossible to designate well by any appellations heretofore employed, the different branches of electrical science. As almost all the phenomena ascribed to Electricity, before the time of Galvani, are due to mechanical causes, I have heretofore concurred with some electricians, in distinguishing the branch under which these phenomena are treated, as "*Mechanical Electricity*;" but it may be objected that the discovery of the magneto-electric machine, and other magneto-electric contrivances, causes another set of phenomena to be produced by mechanical causes. This objection may be mitigated by the fact, that the phenomena created in the last mentioned way, are not the consequence of mechanical causes simply, but of the reiteration by them, of the influence of a magnet. I have, however, subjoined another appellation, "*Electricity proper*," which I should substitute for that first mentioned, were not the retention of a defective name often less disadvantageous than employing a new one, however unexceptionable.

those of the cylinder and of the circular plate, it may be inferred that these are preferable.\* In either case, the friction is produced by the rotation of a shaft, occupying the axis of the cylinder or plate, and fastened by screws or cement. The shaft or axis, being secured in one or more collars like the mandril of a lathe, is turned by a winch, or by a band and wheels, which are so proportioned and arranged as to quicken the motion. In order to prevent that access of the air to the surface of the glass, which causes a loss of electricity, it is usual, besides the cushion, to have a silken flap, of which one border is sewed to the edge of the cushion, so that it may extend from the cushion, till the other border approximates the collectors.

*Electrical Machine, with a Plate four feet in diameter.*

18. The opposite engraving represents a machine, constructed so as to be permanently affixed to the canopy over the hearth of my lecture room.

19. The convenience of having this machine in the situation which it occupies, I have found to exceed my most sanguine expectations; as it is always at hand, yet never in the way. In lecturing, with the aid of a machine on the same level with the lecturer, one of two inconveniences is inevitable. Either the machine will occasionally be between him and a portion of the audience, or he must be between a portion of the audience and the machine. Situated like that which I am about to describe, a machine can neither hide the lecturer, nor be hidden by him. With it its power at his command while kept in motion by an assistant, he has no part of it to reach or to handle besides the knob and sliding rod of the conductor, which is in the most convenient situation.

20. The object of this machine being to obtain a copious supply of electricity for experiments in which the positive excitement is always employed, it was not deemed necessary to insulate the cushions and the axis.

21. The prime conductor is insulated by the same means as those of the horizontal plate machine. (c. 27.) At C C are the collectors. R represents a sliding rod, which may be drawn out to such an extent, as to be brought in contact with any apparatus placed under it upon the table. The cushions are, in their construction, analogous to those described as belonging to the horizontal plate machine, and represented by Fig. 3, (c. 29.) Their situation and mode of their application, must be evident from the representation of them in the figure.

*Engraving and Description of an Electrical Cylinder Machine.*

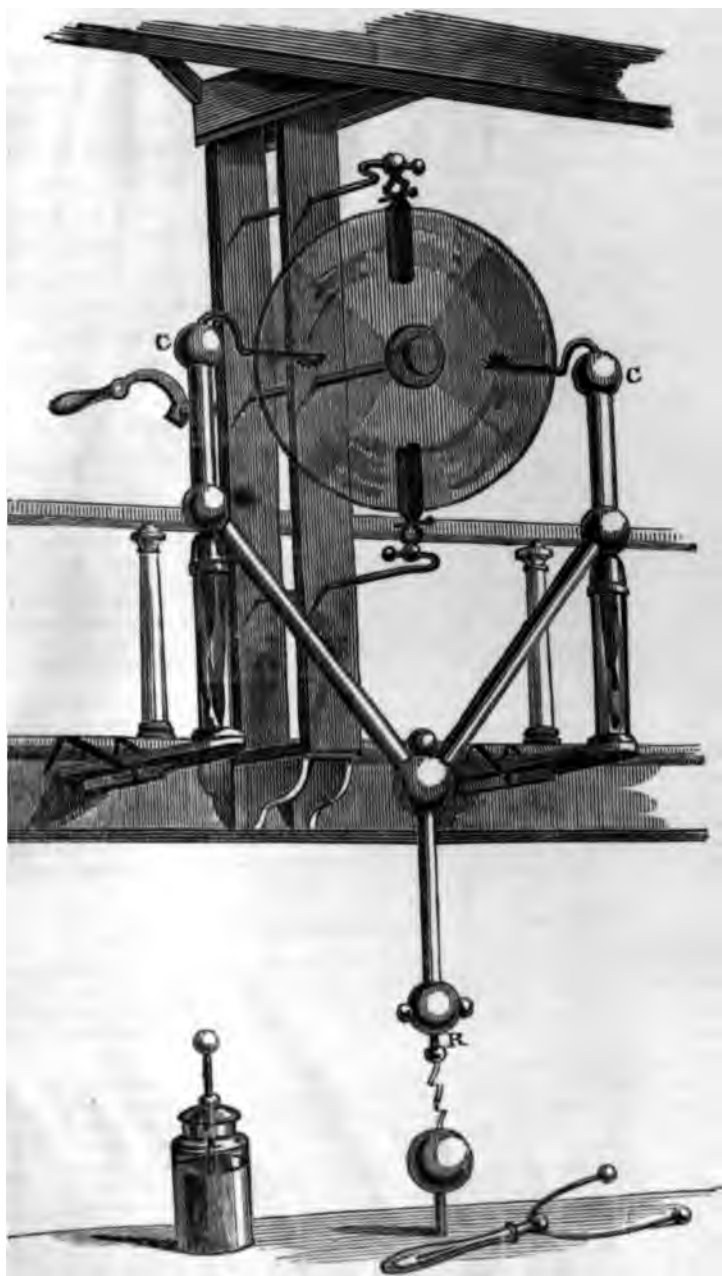
22. A, the glass cylinder—C, the positive, or prime conductor, supported as a glass pillar—E, the collector with its points so projecting as to be quite near to the cylinder. The negative conductor, F, is also upheld by a glass pillar, supporting the rubber or cushion to which the silk flap, G, is attached. By means of a set

---

\* I am under the impression that the great disadvantage attendant on the use of cylinder machines, is the presence of moisture within the cavity, which, being inaccessible, cannot be desiccated. This moisture enables the glass to hold the charge as in a Leyden jar, so that it does not relinquish it to the collectors. The evil thus arising, may be obviated by taking great care, in the construction of the machine, to remove all the moisture by a blast of air rendered anhydrous, and forthwith closing the apertures in the necks, by putting on the caps air-tight. But to keep out moisture, the caps must be of metal; since, if constructed of wood, moisture will penetrate. Moreover, the cement after a time is liable to become leaky. I conceive that it is in consequence of the presence of moisture, that some cylinder machines, which otherwise will not give a spark, perform well after being heated by a hot iron or a pan of coals. These remarks are verified in the case of the cylinder machine, of which an engraving and description is given in the opposite page.



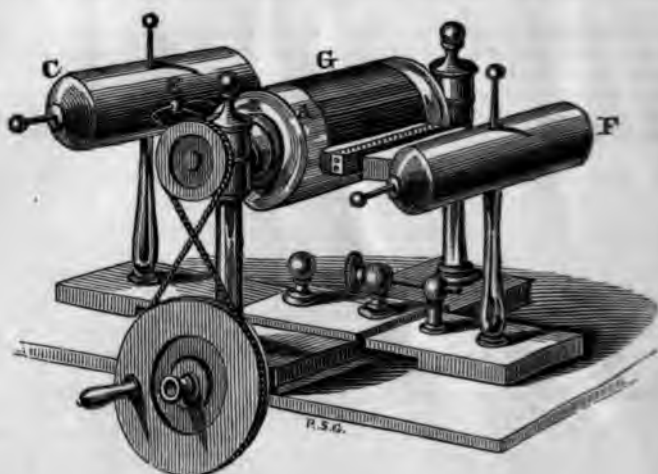
*Large Electrical Plate Machine.*



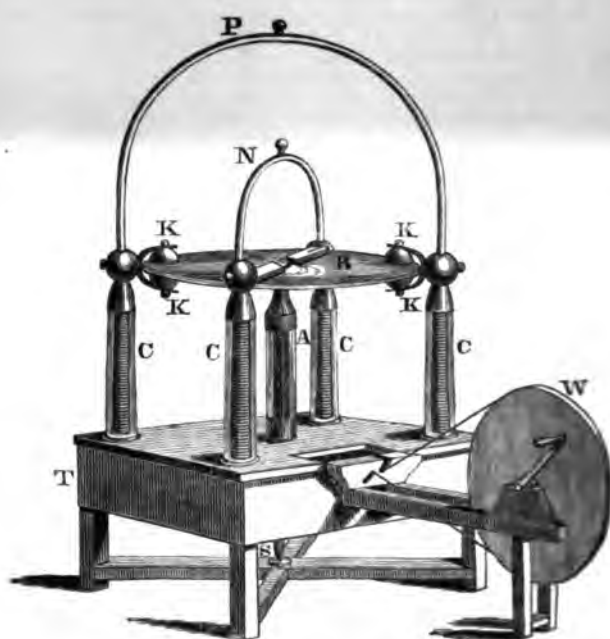




*Electrical Cylinder Machine.*



*Electrical Plate Machine.*



the larger wheel may be made more or less remote from the smaller one, so as to adjust the tension of the band by which motion is communicated to the one from the other.

The former being turned by the winch, causes the smaller one to revolve, and causes the cylinder to the axis of which it is affixed. The revolution of the cylinder while the cushion is pressed against it by a suitable spring, causes the friction which is requisite to excite each portion of the cylinder as it successively passes the cushion. Each of the conductors is furnished with projecting brass knobs, in order to take sparks.

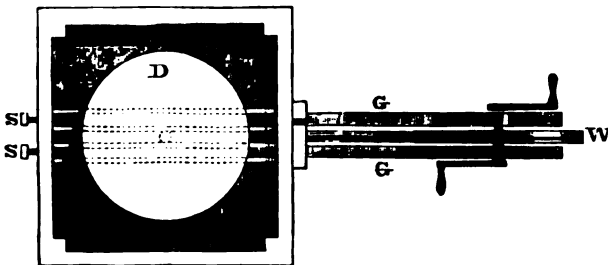
*Description of an Electrical Plate Machine, the Plate mounted horizontally, and so as to show both Negative and Positive Electricity.*

The power of electrical plate machines has been generally admitted to be greater than that of machines with cylinders. The objection to the former has been the difficulty of insulating the cushions, so as to display the negative electricity. Adopting the plate machine contrived by Van Marum, I have read of none in which this difficulty has been surmounted. It is still insisted upon by respectable philosophers, as if it had not been sufficiently removed by his contrivance.

I shall now describe a plate machine, by which both electricities may be produced, and which I have used successfully for eighteen years.

The plate, B, (thirty-five inches in diameter) is supported, as represented in the figure, upon an upright iron bar, about an inch in diameter, covered by a very stout glass cylinder A, four inches and a half in diameter, and sixteen inches in height, not only at the base, through which the bar is introduced, so as to form its axis. The summit of the bar is furnished with a block of wood, turned to fit the cavity, and at the apex of the cylinder, and cemented therein. The external apex of the cylinder is cemented into a brass cap, which carries the plate. The glass cylinder is so fitted as to be able to no strain. It is only pressed where it is interposed between the block of wood within, and the brass cap without. The remaining portion of the cylinder is only its own weight, while it effectually insulates the plate from the iron axis.

The brass cap is surmounted by a screw and flange, by means of which, a corresponding nut, and disks of mahogany, the plate is fastened. A square table serves as a basis for the whole. The iron axis, descending through the top of the table, is furnished with a wooden wheel of about twenty inches in diameter, D, (Fig. 2,) and terminates below this wheel in a brass step, S, supported on the cross of wood, which the legs of the table diagonally together. The wheel, D, is grooved and made to revolve by a band, which proceeds from around a vertical wheel, W, outside of the table. This external wheel has two handles, by means either of one or both of which it may be turned. It is supported on two strips of wood, G G, which, by appropriate screws, (represented at S S, Fig. 2.) may be protruded, lengthwise, from the table, which confine them from moving in any other direction. Consequently, the tension between the wheels may be varied at pleasure, and the tension of the band adjusted.



Nearly the same mode of insulation and support, which is used for the plate, is used in the case of the conductors. These consist, severally, of arched tubes of glass, of about an inch and a quarter in diameter, which pass over the plate from one side of it to the other, so as to be at right angles to, and at a due distance from, the plate. They are terminated by brass balls and caps, which last are cemented on glass cylinders, C C C C, of the same dimensions, nearly, as that which supports the plate. The glass cylinders are suspended upon wooden axes, surmounted by plugs of cork, turned accurately to fit the space which they occupy. The cylinders are

surrounded and secured below, by wooden rings screwed to the table. In the conductors are effectually insulated, while the principal strain is borne by the wooden axes.

28. The form of the collectors (*c. 16*,) must be sufficiently evident from the representation of them in figure 1st. They consist of hollow hemispheres of steel within which several points proceed towards the plate from their centres respectively, where they are attached to the knobs, *k k k k*. The hemispheres are intended to diminish the injurious circulation of air.

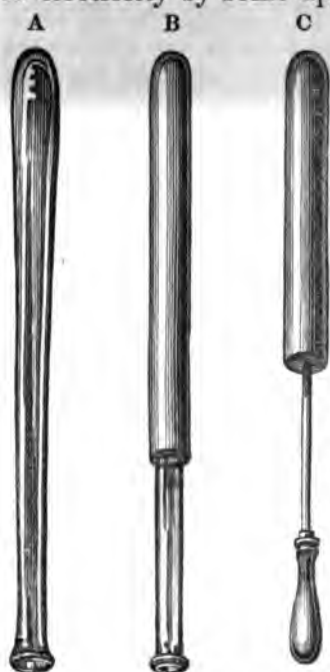
29. The cushions (*c. 16*,) are represented by Fig. 3. These are included by the springs, by which they are made to press with an elastic force upon the surface of the glass, the degree of the pressure being regulated by the screw, *S*.



#### USUAL MEANS OF PRODUCING ELECTRICITY.

30. It has been stated, in the preceding remarks, that an attractive power is acquired by resins, sulphur, and a variety of other substances when rubbed:—also glass bodies, susceptible of this species of excitement, are called electrics, and the principle, on which it is supposed to be dependent, is called electricity.

31. I shall proceed to explain and illustrate the evolution of electricity by some appropriate experiments.



32. A, represents a glass tube; B, a similar tube coated with shell lac, or sealing wax. C, an iron rod, furnished at one end with a wooden handle, and throughout the greater part of its length, it forms the axis of a cylinder of sulphur.

33. When either the vitreous surface of A, the resinous face of B, or the surface of sulphur of C, are rubbed, the former with a leather coated with amalgam and either of the latter with silk or fur, there will be sufficient excitement for the attraction of leaf metal and other light bodies. The amalgamated leather can only be used advantageously with the glass.

*Experimental Illustrations.*

34. Attractive power imparted by friction to amber, glass, resin, sulphur. Large glass tubes rubbed—also, cylinders of sulphur and resin. Thin metallic leaves attracted, at the distance of several inches, either by the glass, the sulphur, or the resin. Electrical machines put in operation.

## COMMUNICATION OF ELECTRICITY.

35. The electric virtue cannot pass from one part of an electric which is excited, to another part without extraneous aid; nor can it pass off, from one electric, through any other. Hence these substances are called non-conductors. Through metals, on the other hand, it escapes instantaneously. It passes through flax or hemp, but not through silk. Water it pervades with great facility, or any thing which contains moisture.

36. Substances which are thus capable of transmitting electricity are called conductors, and are divided into perfect and imperfect conductors. The metals are the only perfect conductors. All other conductors are imperfect; and, at the head of this class, is charcoal, as being the best conductor of electricity next to the metals.

*Experimental Proofs that Electricity cannot pass from one part of an Electric to another, through, or by means of, the Electric.*

*An Experimental Illustration.*

37. One part of a mass of glass, of sulphur, or of resin, being so excited by friction, as to attract light bodies, another, not being rubbed, is not found to attract them; so that the electric virtue does not pass from one part of the mass to another.

*Peale's Experiment.*

38. Among a great abundance of ingenious electrical contrivances, that which we owe, as I believe, to Mr. Franklin Peale, deserves more than ordinary praise for its simplicity of construction, and beauty of effect. One

One modification of Peale's apparatus is represented by the following engraving, which I shall proceed to explain.



39. A bell glass is balanced upon a pivot reaching internally to the apex between wires supported on glass pillars. One wire, A, communicates with the positive, the other, B, with the negative pole of the machine. Under these circumstances, if the machine be put in operation, the portion of the glass next to the wire, A, becomes positively excited, that is, B, negatively excited. Consequently, agreeably to the general law of bodies similarly electrified separate, those dissimilarly electrified approach. Each excited portion of the glass will move away from the wire similarly excited, and will seek that which is differently excited. Thus the excitements changing the situations of the excited parts, and their exchange situation reversing their excitements, a rapid movement must ensue, in the only mode in which it can take place freely; I mean that of a rotation about the pivot.

40. The bell is ornamented by strips of gilt paper, which renders its motion more sensible to the eye; but no coating is requisite to the appropriate effect. A bare bell glass is sufficient.

41. If the metallic band, C, be made to encompass the bell glass, it will be found incapable of receiving any motion from the electrical excitement. In fact, the electric fluid will be seen passing into it on one side, and passing out of it simultaneously on the other side; proving that it cannot, under these circumstances, retain any excitement, in consequence of the conducting power of the metallic band.

42. Mr. Peale's experiment was performed by means of a globular glass vessel with a short neck, or perforation for the admission of the pivot wire. It will be perceived that I have availed myself of this apparatus, to show that the electrical excitement communicated to one part of a non-conducting mass does not extend itself to others; and that consequently in different parts of the same non-conducting mass, opposite kinds of electrical excitement may be produced. It is owing to this property, that the glass bell is put into motion. The electric fluid, being unable to pass along the glass, in its efforts



seek an equilibrium, moves the glass along with it, in consequence of an action arising between each wire, and that part of the glass which has different excitement.

### *Experimental Illustrations.*

13. That the phenomenon owes its existence to the non-conducting power of the glass, is shown by encircling the glass with a metallic band while subjected to the action of a machine as above described. Under these circumstances, as the fluid passes from one side of the glass to the other with perfect ease, that diversity of excitement, which would cause the rotatory motion, cannot arise.

### *Modification of Peale's Experiment.*

4. The following figure shows a modification of Peale's apparatus, by which it is contrived to put three globes in motion.



5. The arched wires, A, B, being severally connected with the different conductors of an electrical machine, cause opposite states of excitement upon the surfaces of the globes, in the neighbourhood of their pointed terminations. A revolution of excited surfaces, arising from the attraction of the differently excited wires, consequently ensues, in a manner analogous to that described in the case of the ball above-mentioned.

### *Additional Illustration.*

6. The principle explained by the preceding experiment receives another amusing illustration by means of an experiment, for the explanation of which the following engraving is intended.

7. A glass ball is supported on a glass plate. On the plate, strips of tin foil are fastened, as to form a broad circle or border near the margin of the plate, and four rods are connected to that circle. There is likewise a flat brass ring, supported and of course insulated by glass pillars, so as to have its inner edge immediately over the exterior surface of the foil.

8. The brass ring being in communication with the prime conductor of the machine in operation, and the tin foil in communication with the cushions, the ring and foil will be oppositely electrified. The ball, being attracted by the ring, becomes positively electrified in the part which comes in contact with it. The part thus electrified will then be attracted by the foil, and communicating its charge, return to



the ring to undergo another change. Different parts in succession undergo these electrical changes, and the consequent movements are, of course, complicated.

49. Peale's apparatus is, however, preferable to this which has just been described, as it is more easy to succeed in making it perform well.

*Experimental Proofs that Metals, Charcoal, Moisture, and Flax or Hemp are Conductors of Electricity, and that Sulphur, Resins, Glass, Silk, and Wool are Nonconductors.*

50. The electrical machine, being in operation so as to emit sparks, or to act upon pith balls, or other light bodies, those electrical effects cease, when the conductor, which is the immediate cause of them, is touched with a rod of metal, or by a piece of charcoal, communicating with the earth; and they are enfeebled, when one end of a hempen or flaxen string is attached to the conductor, while the other end is held in the hand, or lies upon the floor.

51. The conductor being excited, as above described, the phenomena do not cease, in consequence of the contact of a glass rod, or of cylinders of sulphur or resin; nor are

they diminished, by an attachment of woollen or silken rings, as in the case of those of flax or hemp. The glass rod, or the woollen or silken strings, being moistened, the electricity is carried off by them from the conductor. It escapes also readily through a tube filled with water.

#### DIFFERENT KINDS OF ELECTRICITY.

52. It may be learned, from the brief account of the rise and progress of electricity, (c. 7) that the electrical excitement which may be produced in glass, by friction, differs from that which may be produced, by the same means, in resin, or sulphur: that light masses, as paper, or pith balls, separate from each other, when either excitement has been imparted to both: but if one body receives the resinous, the other the vitreous excitement, an attraction between them will ensue. Both excitements, in due proportion, neutralize each other. Also, whenever either excitement is produced, in one body, the other will arise in some other, if both bodies be supported by non-conductors, so as to prevent the escape of electricity as soon as generated. Hence if a person, standing on a glass stool, rub a tube of the same material, he will be found resinously electrified; while any body to which the glass may be presented will be vitreously electrified. A stick of resin, being substituted for the glass, and rubbed in like manner, and under the same circumstances, the same phenomena will appear, in a different order. The person rubbing the resin will be vitreously excited; while the excitement of the body to which it is presented will be resinous.

53. In like manner, when the cylinder of the electrical machine is put in motion, the insulated cushion which rubs it, acquires the resinous excitement, while the prime conductor becomes excited vitreously. If a globe of sulphur or resin were substituted, the cushion would receive the vitreous excitement, while the conductor would be excited resinously.

*Description of Bennet's Gold Leaf Electrometer.*

54. A glass cylinder, supported by a metallic pedestal, is surmounted by a metallic canopy; from the centre of which, two tapering strips of gold leaf are suspended. Strips of tin foil, T T, are pasted on the glass, so as to terminate at the upper ends a little above the level of the lower ends of the gold leaves, and so as to be in contact below, with the pedestal. This should be uninsulated. The gold leaves are more energetically attracted in consequence of the proximity of the tin foil.

*Experimental Illustrations.*

55. The leaves of the electrometer diverge on the approach either of excited sulphur or glass; but when both are approximated to it at once, the leaves will display no divergency.

56. Electrical machine shown, each conductor being furnished with a quadrant electrometer. As the plate is turned, the pith ball of each electrometer rises. As often as a spark is taken from either conductor, the pith ball of the electrometer associated with it falls; and when a metallic wire is made to touch both conductors simultaneously, neither of the pith balls indicates any excitement.

*Of Electric Poles and Electric Circuits.*

57. There is a resemblance, which will hereafter be recurring to, between the reciprocal action of magnets, and that of electrics of which the extremities are in opposite states. Under such circumstances, the poles similarly electrified, or similarly magnetised, appear to repel each other; while those in dissimilar states appear to exercise a reciprocal attraction.

58. The extremities of the magnets, from their exercising a reaction with the terrestrial poles analogous to that which they exercise reciprocally, were called poles; that which is attracted by the north pole of the earth being

designated as the north pole, the other as the south pole. From the analogy, the extremities of excited electrics, and of galvanic and voltaic instruments having properties resembling those of excited electrics, received the same appellation. Hence electricians speak of the positive and the negative poles, of the electric machine, of the galvanic battery, or of a voltaic series, whether in the form of the trough, or of the pile.

59. As a general definition, poles may be alleged to be those parts of an electric, galvanic, or voltaic circuit, at, or between which, ignition, light, chemical decomposition, or sensation are perceived.

60. When the conductors of a machine in operation communicate with each other through a wire or other competent conducting body or bodies, an *electric circuit* is said to be formed. The electric fluid flowing into the cushion from the negative conductor supporting it, is by the electric carried to the conductor which supports the collector, whence, by means of the conducting communication, it returns to the negative conductor. Agreeably to the hypothesis of two fluids, there is in such case a double circuit. Two fluids, separated from each other by the friction, move in opposite directions, and meeting and combining in the conductors as soon as separated, the equilibrium is not sensibly altered.

61. In making or breaking such a circuit, sparks will appear at the time and place, when and where the interruption is such as to allow them to occur. In that case the poles are at the points between which the sparks pass, or indications are afforded of electrical agency.

62. *The poles of an electric machine and the conductors* are often mentioned as if they were identical. In fact the poles are usually at some points in the surfaces of those conductors. They vary, however, at the pleasure of the operator; since they always exist at those parts of the conductors (or of any conducting body or bodies touching one or both) which are nearest to each other, or at which sparks pass.

63. It should be understood that any conductor, especially any perfect conductor, assumes the same electric state as the pole, with which it may be in connexion; and that a contact between either pole, and one extremity of a rod, or wire, transfers the polar influence to the other

end of that rod or wire. The pole is, properly, that point at which the excitement is most active, and experience shows this state to exist always, either at the most prominent part of the electrified mass, or that nearest to any prominent part of the other pole.

64. In operating with an electric machine, of which the rubber is uninsulated, the earth usually forms a part of the circuit, and any conductor, the human body for instance, which, while it has a conducting communication with the earth, happens to be nearest to the positive pole, acts as the negative pole, when the machine is in operation, and there is sufficient proximity. This is indicated by the passage of sparks.

65. I have dwelt upon this subject more particularly as the acceptance of the word pole among men of science has latterly, by its practical and theoretical associations, become of the highest importance. (See my *Treatise on Electro-magnetism*, page 78.)

66. Since the preceding explanation was published, Faraday has suggested that electrical poles as above defined, should be called electrodes; the positive pole being called the anode, the negative pole the cathode. (See my *Treatise on Voltaic Electricity*, page 7.)

#### MEANS OF ACCUMULATING ELECTRICITY.

67. In the case of the insulated conductors of an electrical machine, oppositely excited by the revolution of a glass surface which successively rubs the cushions supported by one of the conductors, and passes under metallic points projecting from the other, it has been shown that it is only necessary to make a communication between them by a perfect conductor, in order to destroy their respective excitements. It follows that the surcharge in the one, must have been just equivalent to the deficiency in the other; and that of course the whole quantity of electricity in the conductors is the same, whether they be in a state of excitement or of neutrality.

68. It has also been shown, that the electric fluid does not pass through electrics, or from one part of an electric to another.

69. I shall now proceed to demonstrate that, if an electric, sufficiently thin and strong, as a pane of glass for instance, be charged on either side with either kind of elec-

ity, the other side of the pane will acquire proportion-  
 a charge of the opposite nature.

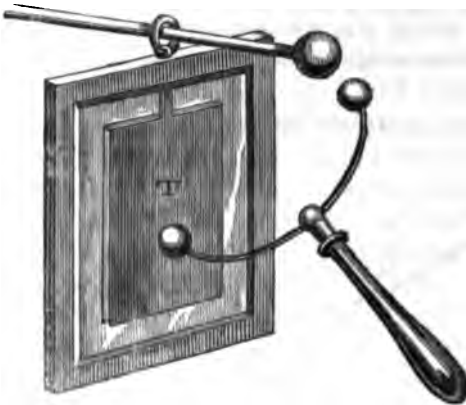
*Experimental Illustrations.*



70. A dry glass pane being held in one hand by its insulating handle, sparks are taken from the excited conductor of an electrical machine, with the knuckle of the other hand. The glass pane, being interposed between the knuckle and the conductor, at first does not appear to intercept the sparks; yet, as they gradually diminish and finally cease, they are obviously intercepted by the pane, sooner or later. The pane being supported by the handle, on touching the surfaces in the part which has been exposed to the sparks with one hand, while the part opposite, on the other side of the pane, is touched by the other hand, an electrical discharge takes place, a shock is experienced, and the electrical excitement disappears.

71. It follows, that the sparks which had apparently passed through the pane, had actually been arrested by the surface nearest to the conductor, and had appeared to reach the hand, because, for every spark received on one side, an equivalent portion of the electric fluid was expelled in the same form from the other side.

*Coated Pane.*



2. A pane of glass having been coated on both sides with tin foil, leaving a space of about two inches from the edge all round; the coatings are made severally to communicate, for a short time, with the two excited conductors of an electrical machine, while in operation, the coatings being otherwise insulated. Thus situated the pane becomes charged with electricity. The different coatings being, in the next place, allowed to communicate with each other through a metallic arc, a discharge en-

sues, more or less powerful, according to the power of the machine, the extent of the coated surface, and the dryness of the air.

#### *Of the Leyden Jar.*



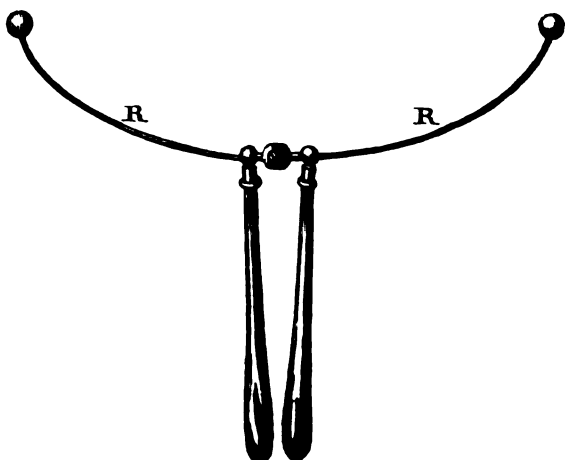
73. In the "*Brief Account*," p. 9, &c.) some account has been given of this celebrated invention. The accompanying cut is a representation of it in an improved form. There is no essential difference between a coated phial, and a coated jar. The existence or absence of curvature does not sensibly affect the result in theory, in practice excepting as respects convenience.

74. The form of the jar is more adapted to the retention of a charge. It does not allow that free intercourse between the inner surface and the air, which carries off the electricity, particularly in each coating.

75. The coating, it will be observed, is represented as extending both on the inside and on the outside, till within a distance from the brim equal to about one-third of the whole height of the jar. The jar is closed by a broad stopple, through the centre of which passes a metallic rod, terminated above by a knob, and below by a spiral of wire, which establishes a secure contact with the inner coating.

76. The most convenient mode of charging such a jar is to grasp it with the hand, and present it to the knob of the prime conductor, when the cushions are uninsulated, or in communication with the outer coating by means of a chain or wire.

#### *Of the Common Discharger.*





77. The instrument, represented by the foregoing figure, is called a **discharger**, being employed to complete the circuit between the oppositely charged surfaces; thus enabling the excess in one to be discharged upon the other.

78. The rods, R, R, are joined by a hinge; so that by means of the glass handles to which they are severally affixed, the terminating knobs may be made to come in contact, or to be more or less remote from each other.

79. *A charge is imparted equally well by the contact, or communication of either coating with either conductor.*

80. The charging of a coated pane or jar may be effected, provided either of the surfaces are in communication with either conductor, the other surface communicating with the other conductor, one or both of the conductors being insulated. In whatever way a charge may be induced, it will be found that the one surface loses as much as the other gains; since a conducting communication is always sufficient to bring them both back to a state of neutrality. Hence as the sum of the quantities on both sides of the pane is always the same, charging the pane does not derange the electrical equilibrium of the surrounding medium.

81. The charge must vary in its strength according to the power of the machine, the dryness of the air, and the thickness of the glass; since the self-repellent power of the electric particles, and their attraction for the negative surface of the glass, must be inversely as the squares of the distances at which they operate.

82. On this account, as a plate of mica may, with less thickness, possess greater strength than a glass pane, it will, in proportion to the respective areas, receive a much higher charge. A certain degree of strength is necessary to enable the glass to resist the intense attraction between the surcharge of electricity on the positive side, and the surface of the glass on the negative side. In obtaining this strength in the glass, we increase the distance between the surfaces, and of course diminish the efficacy of the self-repellent and attractive powers on which the charge depends.

### *Experimental Illustrations.*

83. That the charges may be imparted through either coating by either conductor, shown by duly charging and discharging coated panes and jars.

*Experimental Proofs that the different Surfaces of a charged Leyden jar are oppositely electrified.*



84. If, from the conductor of an electrical machine in operation, a Leyden jar be suspended by a metallic hook, connected with its coatings, it receives no electricity until the other coating is approached by a conducting substance which communicates directly with the other coating of the machine.

85. If one or more bodies, for instance, little metallic bells, qualified to act as bell clappers, be suspended at a suitable distance between bells severally communicating with the coatings of a charged pane or jar, the bells will play between themselves, demonstrating them to be oppositely electrified by their communication with the different surfaces.

*Chime of Bells.*



86. The little metallic balls, *b, b*, and the bell situated between them, being suspended by silk, which is a non-conductor, cannot receive the electrical excitement communicated to the inner coating of the jar. But the two outer bells being suspended by metallic chains from a metallic rod communicating with the inner coating, will partake of the excitement in this coating. Consequently the balls remaining neutral, while the outer bells are excited, are attracted by these, and on coming in contact with them receive a quantity of the electric fluid adequate to bring them to the same degree of excitement. Hence in the next place they separate from these bells, and are attracted by the central bell, which, by means of a chain connecting it with the external surface of the jar, is brought into the same electrical state as this surface, and must of course be in a state opposite to that of the bells communicating with the other surface. The balls, by contact with the central bell, lose as much electricity as will bring them to the same state as this bell, and are then separated from this bell; and are attracted by the others, are again separated, and are again attracted, until by repetition they transfer the surcharge on one surface to the other, and thus restore the equilibrium. Gravitation operating upon the balls as upon the pendulum of a clock, evidently co-operates to sustain their vibrations.

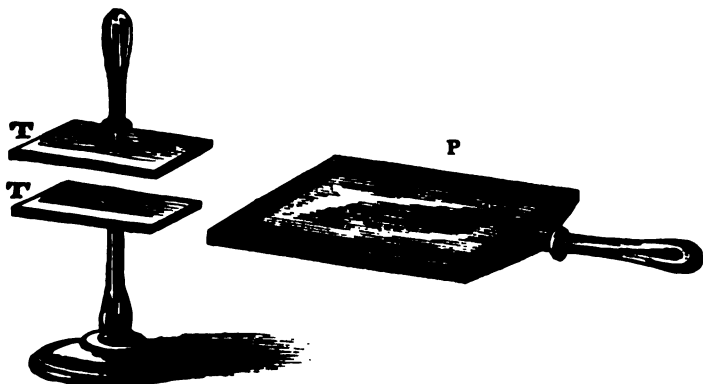
87. The length of time that the balls may be kept ringing by the vibration of the bells, when the air is dry, may excite surprise at first; but it should be recollected that the balls can only carry off at each stroke a portion of the electric fluid, which, to the whole quantity in the coating, as the superficies of the ball is to the surface of the coating; or less, probably, than as one to ten thousand.

*If the part performed by the Coatings in the case of the Leyden Jar, or Coated Pane.*

88. Metallic coatings, employed as in the preceding experiments, are of use in conveying the charge, but do not contain it. The effect of the tin foil is simply to cause the speedy and equal distribution of the electricity over the surface of the glass, which, being an electric, cannot by itself convey the excitement from one part of its surface to another. Hence a pane without coatings can only be partially charged or discharged at one contact.

*Pane with Moveable Coatings.*

89. T T represents metallic sheets, which are used as coatings to a pane, also represented in the figure. One of the sheets is insulated by being supported upon a stand with a glass leg, the other by being held by a glass handle.



*Experimental Illustration.*

90. A glass pane, P, held by means of an insulating handle of the same material, is made to touch the knob of an excited conductor of the electrical machine on one side; while another metallic knob, communicating with the other conductor of the machine, is made to touch the pane on the other side, in the part opposite to the first mentioned knob. By varying the situation of the knobs, the pane is charged wherever its surfaces have been sufficiently in the vicinity of the knobs. If, while so prepared, it be supported by its handle, and one hand of the operator approximated to one side, while the other hand approximates the other, it can only be gradually discharged, as it was charged; the knuckles being made to assume, successively, the various positions relatively to the pane previously occupied by the knobs. But the pane being again charged by the knobs, with the aid of the coatings, T, T, properly applied, the surfaces are thoroughly and instantaneously discharged, if a conducting communication be made between the coatings, by means of the hands, arms, and person of the operator, or by any other conductor.

91. The coatings being applied to the pane whilst charging, and then removed, the discharge can only be effected gradually, as the knobs of the discharger is made to pass over the charged surfaces, the one on one side the other upon the other side of the pane.

92. Any other conducting substance which will accommodate itself to the surface of the glass, may be substituted for tin foil. But metals are preferable, as they are pre-eminently the best conductors.

*Glass Vessel so situated as that Water is made to perform the same office as Metallic Coatings in the Leyden Phial, illustrating the original Experiment of Cuneus and Mushenbroeck.*



93. A glass vessel, containing a quantity of water, of which the surface should not be less than two inches below the brim, and of which the exterior surface should be covered by water to the same height as the inner surface, may, as in the celebrated experiment of Cuneus and Mushenbroeck, be charged and discharged by the same means as the pane or phial coated with tin foil, though less advantageously.

94. Gold, silver, or copper leaf, metallic filings, or mercury, may be substituted for the coatings of a Leyden jar. When metallic filings are glued to the surfaces of a pane or jar within the space usually allotted to the tin foil coatings, the

discontinuity of the conducting surfaces causes the passage of the electricity from one portion of the surface to another to be indicated by splendid coruscations, which will hereafter be fully illustrated.

***Experimental Demonstration that the Charge of a Leyden Jar does not reside in the Coatings.***

95. That the charge does not reside in the coatings, may be proved by removing them, touching them with the hand while separated from the jar, and afterwards replacing them, and making a communication between them. A discharge will take place in the same way as if they had not been removed.



96. Instead of tin foil coatings, a metallic case is made just large enough to receive a tumbler with ease, and reaching about two-thirds of its height. A hollow cylinder of the same material is made so as to fill the cavity of the tumbler to the same height as the case reaches on the outside, and yet so loose as to be removed without difficulty. The tumbler being charged in the usual way, the cylinder may in the first place be lifted out of the tumbler by means of a glass rod, and the tumbler in the next place grasped at the brim, and lifted out of the case without destroying the charge. This is rendered evident by reinstating the tumbler in its case and the cylinder in the tumbler; and by means of the discharger making a conducting communication between the case and the ball of the wire communicating with the cylinder.

der. An electrical spark will then pass with the usual noise. Or, if the circuit be established by touching the knob with one hand, and the case with the other, a shock will be experienced.

***Of Electrical Batteries.***

97. A series of coated jars being placed side by side in a box, and all the inner coatings being made to communicate with each other, and with a ball of metal, by means of metallic rods; and all the outer coatings being made to communicate with each other, and with another metallic ball, by strips of tin foil, the jars thus associated are called an electrical battery.

98. Charging and discharging an electrical battery, however extensive, is just as simple, and is performed in precisely the same way, as in the case of a single jar. To charge a single jar, or a battery, the different coatings must be made to communicate, severally, with the different conductors of an electrical machine, in operation, either directly, or indirectly through the floor of the apartment or other conducting medium.

99. To effect a discharge, either one or several conductors must be made to form a circuit from one coating to the other, either unbroken, or if interrupted, the interval, or the sum of the intervals, must not exceed a certain distance, called the striking distance, and which varies with the power of the electrical machine.

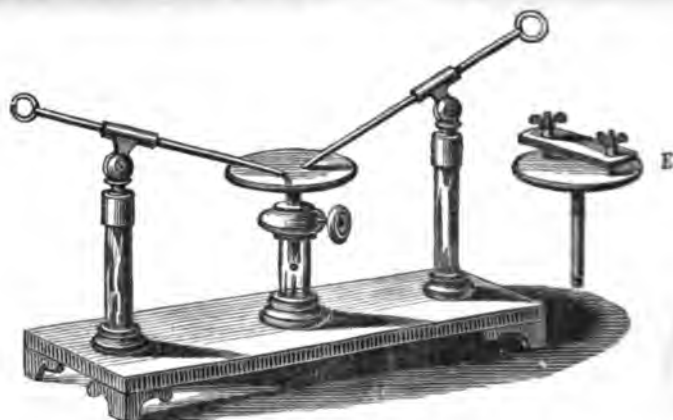
100. Charging a battery will take more or less time, according to the number of jars to be supplied, and the quantity of the electric fluid generated by the machine. But the discharge appears as quick from a great number as from one, notwithstanding the numerous ramifications through which the electricity has to pass.

*Electrical Battery of thirty-two Jars, each thirteen inches in height, and five inches in diameter.*

101. My electrical battery is situated permanently on the external edge of the canopy over the hearth of my lecture room, in the vicinity of my large electrical machine. With the positive conductor of this, it is of course easily made to communicate by a metallic rod. From the outer coating a wire is extended to one of the iron columns of my lecture room, along which it afterwards descends to the table, and, when the battery is in use, a sheet of metal on which the battery discharger is placed.

*Description of Henley's Universal Discharger.*

102. This instrument has been employed to facilitate the exposure of bodies to a discharge from a Leyden jar, or battery.

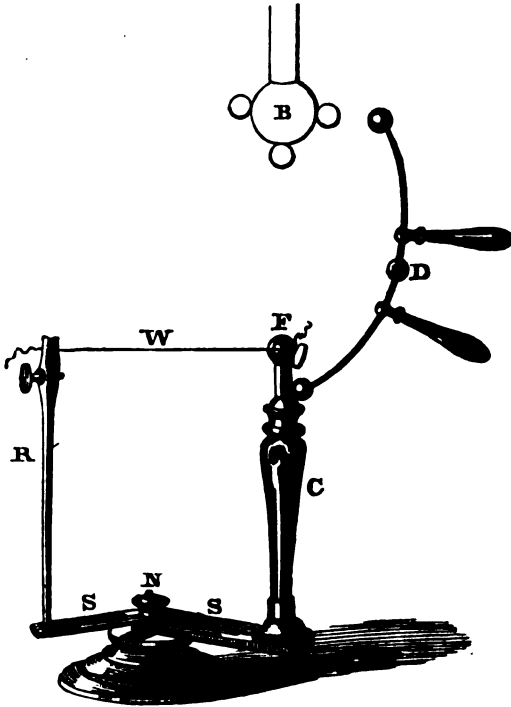


103. It may be understood from inspection. Two rods are supported upon glass pillars, to which they are secured by universal joints, having not only liberty to move on a pivot in almost any direction, but also to be slid through a spring socket, so as to lengthen or shorten the portion of the rod between the socket and the point. The ends of the wires are pointed, but near the points are screws cut so as to fasten to brass balls which may be screwed on or off.

104. Between the columns is a little stand, which may be altered in height by means of a set screw. Upon this stand, an object to be made the medium of a discharge may be placed, the ends of the wires being in due contact with it. To one of the eyes at the other end of the rods, a wire or chain, communicating with a coating of the battery, may be affixed. By means of the common discharger (c. 76) a communication being then made between the other rod and the other coating of the battery, the circuit is completed, and the whole charge of the battery passes through the body upon the stand.

105. In some cases where pressure is required, the stand represented at E is employed. Thus some gold leaf, being compressed between two very small panes of glass, kept together by the screws with which this last mentioned stand is furnished, may be deflagrated, and incorporated with the glass.

*Battery Discharger for deflagrating Wires.*



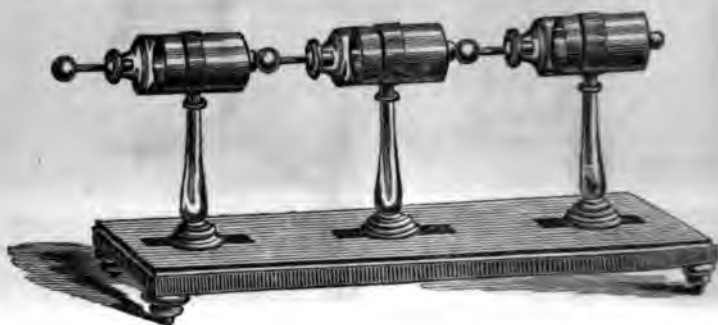
106. This apparatus is employed by me in lieu of Henley's universal discharger above described, being better adapted to my apparatus and mode of operating. Two brass plates are secured to the pedestal by a screw bolt, N, which passes through a hole made in each, near one extremity; the plates are thus allowed a circular motion about the bolt so as to be set in one straight line, or at any angle with each other. On one of the plates near the extremity not secured by the bolt, a brass socket is soldered, into which a glass column is cemented, surmounted by a forceps. At the corresponding end of the other plate there is a brass rod, R, perpendicular to the plate and parallel to the glass column. This rod is also furnished with a forceps. Between this forceps and that at F, supported and insulated by the glass column, C, a wire is stretched, which may be of various lengths, according to the angle which the plates, S, S, make with each other. The pedestal should be metallic, or have a metallic plate at bottom, in communication with the external coating of the battery. This being accomplished, it is only necessary to charge the battery, without subsequently breaking the communication between the inner coatings of the jars and the prime conductor by which the charge is conveyed. In that case, touch-

ing the conductor is equivalent to a contact with the inner coatings of the jar, so far as electrical results are concerned. Hence, by causing one of the knobs of the discharger, D, with glass handles, to be in contact with the insulated forceps, F, and then approximating the other knob to the prime conductor, B, the charge of the battery will pass through the wire, W; as it cannot descend by the glass column, so reach the operator through the glass handles.

### *Of Electrical Excitement by Induction.*

107. The simplest case of this kind is that of the Leyden phial, or coated pane, already illustrated, where one surface being in contact with an excited conductor, a tendency is *induced* in the electricity on the other side of the electric to leave it. Agreeably to the Franklinian theory this arises from the self-repellent power which is presumed to exist between the particles of the electrical fluid.

### *Apparatus for the Illustration of Electrical Induction.*



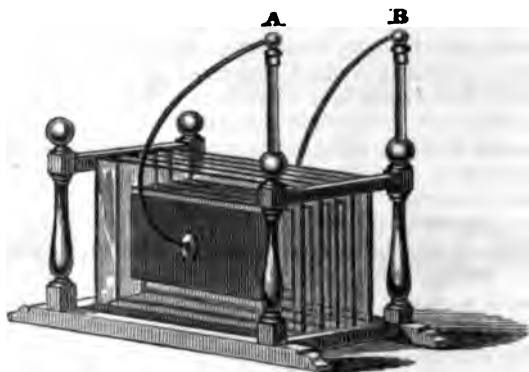
108. If the outer and inner coatings of two or three insulated jars be made to communicate, and the coatings of each extremity of the series be brought into communication with the conductors of a machine in operation, as usual when one jar is to be charged, it will be found that a charge is received by all; and in discharging them a spark may be perceived to pass between each jar, if a small interval be left. The effect of the discharge is less than that which would be produced by means of one jar. In this case the surfaces are said to be charged by *induction*.

109. The number of jars which can be thus affected is greater or less, according to the intensity of the electricity evolved by the machine, and the aggregate thickness of glass interposed.



*A new Apparatus for the Illustration of Electrical Induction.*

110. As the prevailing theories of electricity cannot be understood without a correct idea of electrical induction, I have constructed, for the purpose of rendering it more intelligible, the apparatus described in the following article. The surfaces oppositely charged, being in the case of panes exactly alike, renders their commutable relation more easy to understand; and the process, as it proceeds in them, having a greater resemblance to that ascribed to voltaic series, may hereafter be more advantageously cited as a means of illustration.



111. A series of five panes coated on both sides with tin foil, excepting about two inches from the edges, are situated in a frame at the distance of about two inches apart. A metallic communication is established between the inner coating of the first pane in the row, and that of the second pane immediately opposite, by means of a spiral spring of wire, which, by its pressure, keeps its place, and produces a close contact between its termination and the tin foil. A similar spring is interposed between each pair of coatings. The external coating of the first, and that of the last pane in the series communicate severally by wires with metallic knobs, A, B, supported upon and of course insulated by glass pillars; the coating of the first pane communicating with the knob at A, that of the last with the knob at B.

112. This apparatus, like a Leyden jar, may be charged in either of three modes. That in which only the positive pole of the machine employed is insulated from the earth; that in which only the corresponding negative pole is insulated; and that in which both poles are insulated.

113. When the operation is performed with the positive pole insulated, the negative pole communicating with the earth, the surcharge induced in the coated surface of the first pane expels from the inner coated surface of that pane a portion of electricity, which is of course driven through the spiral into the nearest coated surface of the pane next in order. The surcharge induced thus in the nearer surface of the second pane, causes the other surface of this pane to give up electricity to the nearer surface of the third pane: so that by a repetition of the process, every pane will be charged; the last surface or the external surface of the fifth pane, relinquishing a portion of its electricity to the earth.

114. During the access of the charge, the apparatus only receives an accession of the fluid on the external coated surface of the first pane, and loses a portion from that of the last pane. In the other surfaces the quantity is not altered; since whatever one loses is gained by another with which it communicates.

115. When the operation is performed with the negative pole in a state of insulation, it will be the converse of that above described. Electricity being abstracted from the external surface of the fifth pane, instead of being accumulated upon that of the first pane, the internal surface of the fifth pane becomes positively excited at the expense of the nearest surface of the fourth pane, which of course becomes negative on the surface thus robbed, and positive on the other side, at the expense of the coated surface of the third pane. Thus by a successive inductive influence, transmitted from pane to pane, every other surface is negatively charged, causing those which alternate with them to be charged in the opposite way.

116. When the knobs, A and B, are acted upon by a machine with both poles insulated, the two processes above described co-operate simultaneously; since, while electricity is abstracted from the external surface in direct communication with B, on the right, it is accumulated upon the external surface communicating with A, on the left; so that, by the inductive process, each pane becomes charged.

117. In whichever of these modes a charge may be imparted a discharge of all the surfaces may be effected by making a conducting communication between the external surfaces of the first and fifth pane by touching the knobs A and B, severally communicating with them, by a discharger. The only difference consequent to the different modes of charging is in the state of the charge relatively to that of the earth, which is conventionally identified with neutrality.

118. Each mode of charging is productive of a different state of the pane relatively to the neutral state. Whichever of the knobs A, B, and of course the surfaces of the first and fifth pane communicating with them is in communication simultaneously with the earth and a conductor of the machine, must have the same state as the earth, and must consequently be neutral. The other knob, and its connected coated surface, must have the excitement of this conductor. It follows, that in the case in which one knob, A, should communicate with the excited positive conductor while the knob, B, communicates with the other conductor and with the earth, the negative surfaces of all the panes, excepting the external surface of the fifth pane, will be positive relatively to the earth. And, vice versa, that if A communicate with the negative conductor, B, being uninsulated, as above described, all the positive surfaces of the pane, excepting the first, communicating with A, will be negative relatively to the earth. When both conductors of the machine are insulated, and severally while excited in communication, the one with A, the other with B, the coatings of the central pane will be neutral, while all those between that pane and the knob communicating with the positive conductor will be relatively positive, while all on the other side of it will be relatively negative. To the student, who shall follow me in this explanation, it will be quite evident that positive and negative electricity are relative states, and that a body, E, may be negative as respects D, yet positive as respects F. When this apparatus is discharged as above described, the surcharge in the surface of one of the extreme panes, compensates the deficiency in that of the other extreme pane; and, at the same time, the equilibrium is restored between all the intermediate surfaces. As re-

**pects** these there has been no loss or gain of the electric fluid. The actual **changes** have only amounted to a transfer and retransfer from one set of **the** surfaces to another.

### *Exposition of the difference between Induction and Conduction.*

**119.** There is a great analogy between the process by which an excess of electricity in one body is conveyed to another through a conductor, and **hat** in which the air condensed in one vessel is conveyed to another through a tube, in order to attain an equilibrium. But when the process by which a body, surcharged with electricity, electrifies another body, inductively, is compared with any which can exist between a cavity surcharged with air, and another in its vicinity, no analogy can be discovered. However air may be condensed in one receiver, it has no influence upon the quantity which can be retained by a neighbouring receiver with which no channel of communication exists. That removal of all obstruction to the transfer of the redundant fluid, which is the effect of the conducting process, would be fatal to the process of induction. This requires that no means of conveyance shall exist between the electrified body and that subjected to its inductive influence. Moreover, the excitement produced by conduction, is the same as that of the exciting body, while that which results from induction is the opposite of the kind by which it is induced. Nevertheless, a body charged by conduction may produce a charge by induction; and a charge by induction, may be discharged by conduction.

### *Of Dynamic Electrical Induction.*

**120.** Besides that kind of *statical* electrical induction, which I have been endeavouring to explain, there is another kind which may be called *dynamic* electrical induction. For our knowledge of this species of electrical reaction, we are indebted to Faraday. It is in fact to this habitude of electricity, that the Faradian currents are attributable, respecting which I have treated briefly in my Treatise on Electro-magnetism, page 60. The experiments of Henry, mentioned page 57, of same treatise, afford an illustration of the analogy between the dynamic inductive influence of electricity proper, and that excited by galvano-chemical reaction.

### MEANS OF DETECTING OR MEASURING ELECTRICITY.

**121.** It has been seen that the property which light bodies have of separating from, or approaching to, each other when electrified, has been of use in showing the nature and extent of electrical excitement.

**122.** A ball of pith, supported by a radius, suspended from a pivot, so as to be capable of describing an arc of ninety degrees, over a corresponding curved scale, constitutes Henley's quadrant electrometer, employed in the experimental illustrations. (*e.* 130.)

**123.** Bennet's electrometer has been described, in which metallic leaves are suspended within a glass cylinder, to a metallic cap; slips of tin foil being pasted on the glass, opposite and parallel to the gold leaves.

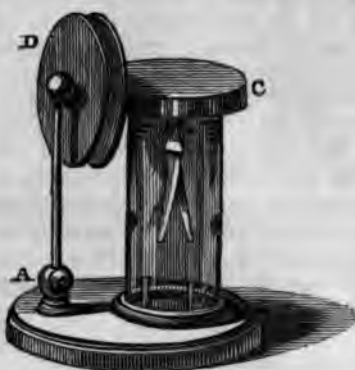
**124.** This last mentioned instrument is sometimes more properly called an electroscope; as it is better calculated to discover electricity than to measure it.

**125.** The efficacy of the gold leaf electroscope is much increased by the addition of two metallic disks, one soldered to the cap, the other attached

to the foot by a hinge; so as that it may be placed parallel, and as the first mentioned disk as it can be without touching. In this capacity for electricity of the disk attached to the cap is found to be increased by *induction*; so that it will receive a surcharge. When they are separated, the excess of electricity received while they were together, is indicated by the divergence of the leaves.

126. The instrument thus constituted, is called the *condensing electrometer*, of which an engraving and description is annexed.

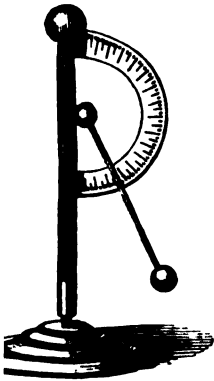
*Description of the Condensing Electrometer.*



127. The condensing electrometer, of which the annexed figure is a representation, differs from the ordinary instrument, in being furnished with two metallic disks, one fixed to the canopy, C, the other held by a wire. The wire terminates in a hinge at A, by which the disk which it supports may be made to approach, or retire from the fixed disk. The metallic hinge communicates, by a strip of tin foil, with other strips of the same metal, which are pasted on the glass body. This is the case of the gold leaf electrometer. (c. 54.)

128. In order to put this instrument into operation, the disks must be placed quite parallel, and as near each other as possible without touching. On touching the cap with an electrified mass, containing a charge of electricity otherwise too low to affect the leaves, and afterwards removing the disk D to the distance of two or three inches, the leaves diverge. The divergence of the leaves of the condensing electrometer may be produced by supporting a zinc disk of about six inches in diameter, in the hand, or otherwise, so as to have a communication, directly or indirectly, with the pedestal of the electrometer, and placing on it, from ten to twenty thin disks of copper of the same size, held by a glass handle, and at removal bringing the copper disk in contact with the cap of the electrometer. By these means a charge is imparted to the cap, which, when the outer disk is removed, is evinced by the divergency of the leaves. Our knowledge of the last mentioned method of producing electricity by the contact of heterogeneous metals, we are indebted, I believe, to the celebrated Volta.

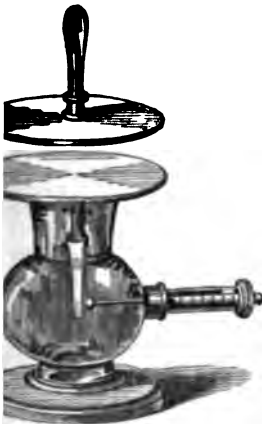
129. I have constructed an electroscope, with a single leaf, to which a brass ball may be approximated by a micrometer screw. This is more sensitive than any electrometer which I have seen on the usual plan. When furnished with a cap of zinc, if a plate of copper be placed over the cap, and then lifted, the leaf will strike the ball. This instrument acts as an electroscope and as an electrometer, as it detects and measures the minutest degree of excitement.

*Description of Henley's Quadrant Electrometer.*

130. Henley's electrometer consists of a little wooden column, supporting a semicircle of ivory, or of wood covered with white paper, graduated near the periphery into 180 degrees. At the centre of the semicircle there is a pin, from which a moveable radius terminated by a pith ball is suspended. This radius is sufficiently long to allow the ball to reach to the base of the column, against which, when left to itself, it rests. But when the ball and column are electrified, the ball moves off from the column, together with the radius to which it is affixed. But the radius being secured to the pivot at its upper end, the ball must describe a greater or less portion of a circle, which is at the same time indicated and measured by the graduation.

*Description of the Single Leaf Electrometer, by which the Electricity, excited by the touch of heterogeneous Metals, is rendered obvious after a single contact.*

1. A single gold leaf is suspended from a disk of zinc six inches in diameter, which constitutes the cap of the instrument. Opposite to this single leaf a ball is mounted, which may be made to approach the leaf, or recede from it, by means of a screw. Of the same size as the disk which forms the cap there is a copper disk with a glass handle, accompanying the instrument.\*



132. The electricity produced by the contact of copper and zinc, is rendered sensible in the following manner. Place the disk of copper on the disk of zinc, which forms the cap of the electrometer. Take the micrometer screw in one hand, touch the copper disk with the other, and then lift this disk from the zinc. Usually, as soon as the separation is effected, the gold leaf will strike the ball, if the one be not more than the twentieth of an inch apart from the other. Ten contacts of the same disks of copper and zinc will be found necessary to produce a sensible divergency in the leaves of the condensing electrometer. That the phenomenon arises from the dissimilarity of the metals, is easily shown by repeating the experiment with a zinc disk, in lieu of a disk of copper. The separation of the homogeneous disks will not be found to produce any contact between the leaf and ball. I believe this to be the only

case in which the electrical excitement, produced by the contact of heterogeneous metals, can be made evident without the aid of a condenser.

33. It is probable that the sensibility of this instrument is dependent on that property of electricity which causes any surcharge of it, which may be created in a conducting surface, to seek an exit at the most projecting termination, or point, connected with the surface. This disposition is no doubt rendered greater by the proximity of the ball, which increases the capacity of the gold leaf to receive the charge, in the same manner as the uninsulated disk of a condenser, (c. 27,) increases the electrical capacity of the insulated disk in its neighbourhood.

34. It must not be expected that the phenomenon above described can be produced in weather unfavourable to electricity. Under favourable circumstances, I

For the experiment with this electrometer, a metallic handle would answer. Being of glass, enabled me to compare the indication, thus obtained by my instrument, with that obtained by a condenser.

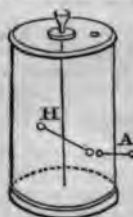
have produced it by means of a smaller electrometer, of which the disks were two and a half inches in diameter.\*

135. The construction, as respects the leaf and ball, regulated by the micrometer screw, remaining the same, the cap of a condensing electrometer and its dial may be substituted for the zinc disk.

### *Description of Coulomb's Electrometer.*

136. The electrometer of Coulomb is suitable rather for the investigation than for the illustration of electrical phenomena. Yet, as it may be proper to convey an idea of the principle of this instrument, I shall quote from the *Treatise on Heat and Electricity* of the distinguished Dr. Thomson of Glasgow, a description, accompanied by an engraving of the electrometer in question in the most simple form. Alluding to the gold leaf electrometer (c. 54,) or that in which straws are used in place of gold leaves, Dr. Thomson observes:—

137. "In these and many other common electrometers which I think it needs to describe, the instrument cannot be considered as a true measure of the quantity of electricity; because as the two straws or the two slips of gold leaf separate farther and farther from each other, it is evident that gravitation will act more and more powerfully to bring them back again to their naturally vertical position. Hence the repulsive force of the straws, or leaf, is not proportional to the distance to which they separate from each other. These instruments cannot of course be employed to measure the energy of electricity.



138. "But the electrometer of Coulomb is free from this defect. It is represented in the margin. It consists of a glass vessel having a lid also of glass, in the centre of which a small hole is bored. Through this hole passes an untwisted raw silk thread four inches long, and fixed at the top to a micrometer, by means of which it may be turned round any number of degrees at pleasure. To the silk thread is attached a very fine gum lac thread, *H*, having at each extremity a small knob. This lac needle, with its knob, weighs only one-fourth of a grain. A small hole is drilled in the side of the vessel, at *A*, through which passes a fine wire terminated at both extremities by a knob. When an excited body is placed in contact with the knob at *A*, the knob at the other extremity will acquire the same electricity as the excited body. This electricity it will communicate to the knob of the lac needle suspended by the silk thread which we previously almost in contact, and the two knobs will repel each other. The movable knob attached by the silk thread will separate from the other, and the quantity of electricity will be proportional to the distance to which it is driven off.

139. "Coulomb's electrical balance is an instrument intended to measure the quantity of electricity in bodies, and indispensable in accurate experiments."

140. It should be understood that in this instrument, the knob of the suspended needle may be made to resist sufficiently its removal from that supported by the wire, by twisting the silken fibre. Coulomb contrived a more perfect and complicated electrometer, upon the same principle as the one which I have described, but furnished with graduated circles for measuring the distance between the balls, and the extent of the torsion given to the suspending filament.†

141. By means of this apparatus, Coulomb confirmed an observation previously made by the Earl of Stanhope, that the density of electricity in the electrical atmosphere, surrounding an excited body, diminishes inversely as the square of the distance from the charged body. Coulomb inferred, from the law thus assumed to exist, and from ingenious and accurate experiments tending to corroborate his inference, that the electricity accumulated about a conducting body is entirely superficial, none of it existing in the interior of the body. He also, as Dr. Thomson conceives, "proved by very simple but convincing experiments, that electricity deposits itself upon bodies according to their surfaces; that it has no more attraction for one body than for another: also, that if two bodies, having the same surface, be placed in contact, whatever their nature may be, any electrical surcharge in either will be

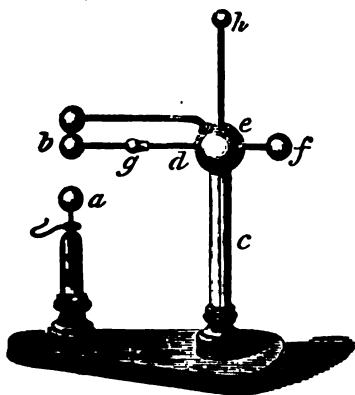
\* I think I have seen an effect from a disk only an inch in diameter, or from a zinc disk having a handle with a copper socket.

† The description of this last mentioned instrument, with engravings, occupies three pages in the *Treatise* of Dr. Thomson, alluded to above, which is more space than I deem it expedient to devote to the same purpose.

divided equally between them." Allowance is to be made for the obstruction arising from the diversity of conducting power, which, however, only delays the equalization, but does not prevent it from taking place.

*Of Cuthbertson's Balance Electrometer.*

142. The following figure affords a faithful idea of this instrument. Of which I shall proceed to give an explanation.



143. The brass ball, *a*, surmounts a rod of the same metal, upon the lower end of which a cork is secured. This cork may be slid upwards or downwards, within the glass tube supporting it, like the piston of a syringe. By these means the ball, while insulated by the glass, is liable to be so varied in its height, as to be supported at any eligible distance from the ball, *b*, beneath which it is situated. This last mentioned ball, *b*, and the rest of the apparatus with which it is associated, is supported and insulated by means of the glass leg, *c*. The ball, *b*, is attached to the end of the rod,

*d*, which is balanced upon a fulcrum within the hollow globe, *e*, in the same way as the beam of a steelyard. The ball, *f*, is made just heavy enough to counterbalance the ball, *b*, together with the sliding weight, *g*, when this weight is at the greatest possible distance from the fulcrum.

144. The globe, *c*, supports two rods, one proceeding from it vertically and surmounted by the ball, *h*, the other proceeding from it horizontally, so as to be in contact with the ball, *b*, as represented.

145. When, previously to the charging of a Leyden jar, the ball, *a*, is made to communicate with one coating, the outer one, for instance, while the rest of the balls and the lever communicate with the other coating, the balls, *a* and *b*, are made to attract each other with a force proportionable to the intensity of the charge and their proximity. Hence, by approximating *a* to *b*, or by sliding the weight, *g*, further from the fulcrum, the resistance of the counterweight, *f*, may be rendered inadequate to counteract the electrical attraction produced by a very low charge. Whenever this takes place, the ball, *b*, will descend until the interval between it and *a*, is so small, that the electric fluid can leap through it so as to discharge the jar or battery. On the other hand, by increasing the distance between *a* and *b*, or lessening that between the fulcrum and *g*, a proportionably higher charge will be requisite to overcome the resistance of the loaded ball, *f*, so as to allow *b* to descend sufficiently to enable the discharge to ensue.

146. It follows from the construction of this electrometer, as explained, that we can cause successive discharges of exactly the same strength, by keeping the distance between the balls *a* and *b*, and that between the weight *g*, and the fulcrum unchanged. It must likewise be evident, that the intensity of the charges, and consequently of the discharges and shocks given, may be regulated by altering the distance between the balls, or that between the sliding weight *g*, and its fulcrum within the globe, *e*.

147. There is a most interesting analogy between the descent of the ball *b*, and that of the cloud of an incipient tornado. If some pith balls be supported in a shallow cup, upon the ball *a*, they will be seen to ascend towards

the ball, *b*, when descending in obedience to electrical attraction, as in case of meteors of the kind abovementioned, water and other moving bodies may be seen to rise up toward the descending cloud.

#### EFFECTS OF ELECTRICITY.

148. The separation or approximation of electrified bodies, the extrication of light and heat, and the shock given to the animal frame, having been all, more or less, subjects of discussion, or adduced as the means of experimental illustration, it may now be proper to display a greater variety of electrical phenomena, and such as being more complicated require undivided attention on the part of those who would comprehend them.

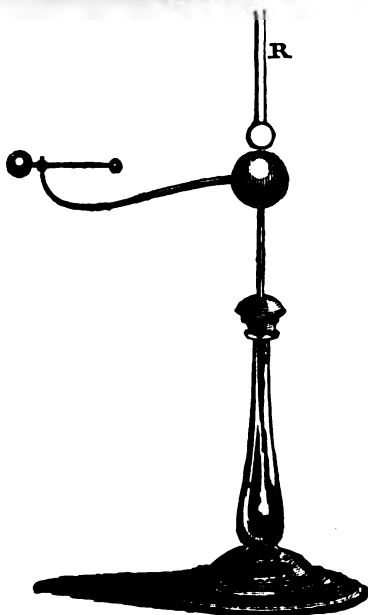
*Of Electrical Attraction.—Of Electrical Light.—Of Electrical Ignition.—Of the Electrical Shock.—Of Mitigating the Effects of Electricity.*

#### *Of Electrical Attraction.*

149. Under this head are placed both the separation and approximation of light bodies, when electrified; since the former, though commonly ascribed to repulsion, is really, as I conceive, the effect of attraction.

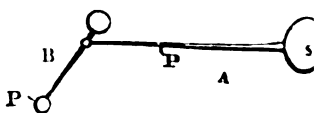
#### *Revolution of a Sun, Planet and Satellite.*

Fig. 1.



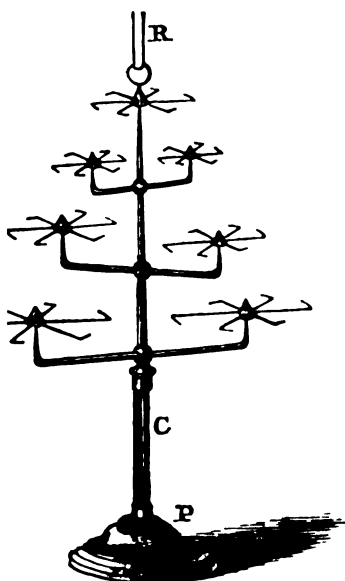
150. A hollow brass globe, 1, is rendered much heavier on one side by running into it a quantity of molten lead, sufficient to occupy about one-third of the cavity. By these means, when supported on a pivot, it preserves a proper position, although on the other side not furnished with lead, it is made to support an arm and two balls: the larger, representing a planet, the other smaller, representing its satellite. These are carried upon different ends of a wire that passes through their axis, and balances upon the point of the arm, so that the balls may counterpoise each other. From the larger arm, a line is drawn, and from the smaller ball, points *P*, are projected, as represented in Fig. 2.

Fig. 2.





11. When the sliding rod of the conductor, R, is brought sufficiently to the central globe of this apparatus, the machine being in operation, ensues a complicated revolution. The planet and its satellite, attached to arm B, are balanced upon a pivot, formed of the recurved and pointed extremities of the larger arm, A; meanwhile the pivot revolving as the globe S, turns upon its axis, carries the planet and satellite in their orbit, as they revolve about the pivot as their common centre of gravity.
12. According to the Franklinian theory, the above described rotatory motions result from the attraction of the surrounding medium, operating incessantly at every part of the orbit, to separate the electrified air from metallic points by which it is electrified.
13. It must be admitted that as these rotatory motions may be produced, whether the excitement be negative or positive, the rationale is more difficult of conception upon the theory of one fluid than upon that of two. It is necessary, agreeably to the Franklinian doctrine, to ascribe all cases in which electrified masses separate from each other, to attraction between them and the matter of the adjoining medium. This process becomes exceedingly difficult to follow in the "mind's eye," when the masses thus separated are undergoing a rapid change of position.
14. The explanation, supposing two fluids to exist, is simply that bodies equally excited repel each other; and consequently that repulsion arises between the points and the air which they electrify, whether the excitement be vitreous or resinous.

*Electrical Tree.*

155. I believe that an apparatus resembling that of which this figure is an engraving, is named in Pixii's catalogue, "*Arbre Electrique*," a name which I have used for want of a better.

156. It consists of several sets of branches formed of wire. Each set is associated by a common hollow brass cone, into the apex of which a recurved wire, forming a principal branch of the electrical tree, is so introduced as to form a support and a pivot, upon which the cone and its branches may rotate. Each rotatory branch is recurved, and terminates in a point; the points in each set projecting in the same direction, so as to co-operate in producing a circular motion.

157. The branches are put into operation by communicating with the machine, as usual, by the rod R. The excitement thus received cannot pass off by the trunk C, which is of glass, cemented into an upright brass rod above, and the pedestal P, below. It can hardly be necessary to add, that the ra-

te of the rapid rotation of each set of the branches is analogous to that of the spinning experiment. In consequence of their being similarly surcharged with electricity, or similarly deficient, the adjoining neutral medium attracts the air and separates them apart with energy, and thus causes them to recede from each other as they come into proximity.

To render the Franklinian rationale more intelligible, as applied to this experiment, and that of the miniature sun, earth, and moon, it may be observed, that

the excitement of the machine being communicated by the sliding rod R, to central ball, and of course to all of the metallic wires therewith associated, diffused through the points to the air in their vicinity. Consequently the points (fig. 2,) and the air electrified by them, being similarly surcharged, or similarly deficient, must be attracted by the adjoining neutral medium; and not attracting other, they are made to separate rapidly, or to move in opposite directions. The process being reiterated with inconceivable speed, the revolutions proceed with proportional velocity.

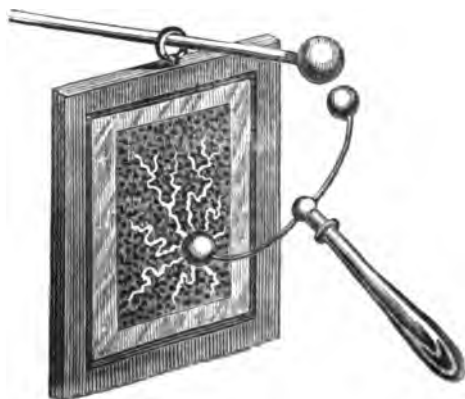
#### *Electrical Hail.*



159. This experiment, which Pixii's Catalogue described as "Electric Hail," (electrical hail) affords another illustration of the movements which may be produced in light dies by electrical attraction. A metallic rod supports one ball within the bell glass, another without, and is to be in contact with the knob of another rod, R, proceeding from the conductor of the large electrical machine in operation. The knob being by these means intensely electrified, attracts some of the pith balls which lie upon the metallic dish which the bell is situated, and which should communicate with the terminals of the machine. As some pith balls come in contact with the electrified ball, becoming similarly excited, agreeably to the general law they recede from each other, and are attracted by the oppositely electrified dish. Reaching the dish they are at the same electrical state as at first, and of course are liable to be attracted again. Meanwhile other balls are undergoing the same routine, producing that contrariety of movements which characterizes the fall of hail.

#### OF ELECTRICAL LIGHT.

*Experimental Illustration of the efflux and afflux of the Electric Fluid during the charging and discharging of coated surfaces, as rendered evident by means of discontinuous coatings of Metallic Filings.*



160. The charging and discharging of a coated surface has already been illustrated and explained. The process is, however, rendered much more interesting, when, instead of a continuous coating of foil, a covering of metallic filings is applied, so as to leave a multitude of minute intervals between the particles of the metal. It is only necessary to have the discontinuity of

ring on one of the surfaces; the other may be coated with tin foil as usual.

161. The tin foil coating should, by means of a strip of the same substance, communicate with the ring attached to the wooden frame in which the pane is secured. Let the pane, thus prepared, be suspended by the g, as represented in the engraving, from a rod affixed to the conductor of a powerful electrical machine in operation. As represented in the figure, a discharger be so held, in contact with the surface coated with filings, to carry off electricity from it, allowing the other surface of the pane to proportionably surcharged. In the next place, let the discharger be so



rotated, as to complete the circuit between the surfaces, allowing the surcharge in the one to rush to the other. By these means the efflux and afflux of the electric matter will be indicated by coruscations of electric light with an indescribable splendour, which will appear so long as the surface coated with tin foil remains in communication with a machine sufficiently active, and the situations of the discharger are alternated as above described.

162. Analogous results may be obtained by means of a jar represented by the preceding figure, which has a hook wherewith to suspend it; or still more advantageously by means of a large carboy, silvered with an appropriate amalgam within, and on the outside furnished with a discontinuous coating of filings.

163. If the discharger employed in this experiment have a glass handle, either the metallic socket, S, into which the handle is cemented, must be touched by one of the fingers, or a wire must be attached to it, making a communication with the negative conductor, directly or indirectly. Otherwise, the external coating being insulated, electricity could not escape from it, and of course the inner surface could not be charged as already demonstrated.



164. The adjoining cut represents a glass carboy of about five gallons in capacity, coated internally by means of the amalgam usually employed for the purpose; externally by brass filings, as in the cases of the pane and phial above described. It is situated under the projecting ball of the prime conductor, so that the knob at the top of the rod, proceeding through a cork from the internal coating, may be in contact with the sliding rod, R, of that conductor. The wire, W, is supported on a pedestal in contact

with the external coating of the carboy, and in communication with the conductor of the machine. Hence, when by the operation of the electrical the internal surface of the glass is becoming charged, the escape of the from the external surface is indicated by coruscations of light, and sounds, as in the preceding experiments; and at the instant when the requires sufficient intensity to jump through the interval between the knob to the ball, and that supported by the wire, at K, the deficit created internal surface being restored at once, the coruscations and sparkling are splendid.

*Long Zigzag or Erratic Spark, contrasted with the Short Straight Spark.*



165. The object of this engraving is to represent the different forms of the electric spark, which take place between a large and a small ball, and how they are made negative or positive. The long and zigzag, or erratic spark A, takes place between a small ball attached to the positive pole, and a large one associated with the negative pole. The short straight spark B, is observed under circumstances the reverse of the just mentioned. They are represented as simultaneous, but, with the same success, and can of course only be obtained in succession.

166. In no respect do the phenomena of mechanical electricity appear more favourable to the Franklinian theory than the more inexplicable according to the theory of two fluids, than in the diversity of the electrical spark in passing between a small ball and a large metallic ball, according to the manner in which the balls are associated with the positive or negative pole of the machine. When the small ball is attached to the positive pole, the spark is comparatively narrow, and of a zigzag shape, such as lightning is often observed to assume; but when the situation of the balls is reversed, the spark is straight, thick, not one-third as long, and of a zigzag shape can be observed.

167. According to the Franklinian theory, when any body is highly charged with electricity than the adjoining bodies, the excess of electric fluid is attracted by them, while it is inadequately repelled by the quantity of the electric fluid, with which they are imbued. It follows that when a small globe is made positive in the neighbourhood of a large excited metal in the latter. When the small globe is made negative, the metal of which it consists attracts all the electric matter in the large globe. Hence there is this difference in the two cases; the small globe being positive, a comparatively small *moveable mass* of electric matter is attracted

in a large immoveable mass of metal: the small globe being made negative, a large *moveable mass* of electric matter is attracted by a small immoveable mass of metal. The charge being in both cases the effect of the same machine, the attractive power must be as great in one case as in the other. The forces by which the masses are actuated being therefore equal, it is quite reasonable that the greatest projectile power should be attained, when the small mass is moveable. In that case, it will require less air to be removed in order to effect a passage.

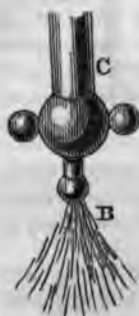
168. There is an analogy between the difference which I suppose to exist in the case under consideration, and that which may be observed between the penetrating power of a rod which is blunt, and one which is pointed.

169. It remains to be shown why a large mass of electric matter will be discharged in a spark when there is sufficient proximity; although that electric matter be situated in the large globe, and attracted by the other, under circumstances in which, as above stated, it would not pass without great proximity.

170. It must be evident that attraction increases as the distance between the bodies which exercise it lessens. Of course the attraction of the small globe must always act more powerfully on those portions of the electric fluid, which occupy the nearest parts of the positively excited globe. But this difference of distance, and consequent diversity of attraction, increases as the globes are approximated. Thus that portion of the electric fluid which sustains this pre-eminent attraction, will be accumulated into a point; the acuteness of which, and attraction causing the acuteness, increasing with the proximity, there will at last be sufficient projectile and penetrative power to break through the air, and thus open a passage for the whole of the quantity attracted by the small negatively excited globe.

171. When, by the process last described, the fluid is made to leap through a comparatively small interval, by the concentrated attraction exercised by a small negative ball upon the expanded surface of electric matter diffused through a large globe; the air does not become sufficiently condensed to resist it before it reaches its destination, and, of course, it cannot assume the erratic form which would arise from repeated changes in its course, as in the instance of the long spark.

172. Faraday conceives that his late researches warrant the inference that the diversity between the positive and the negative spark, is affected by the nature of the gas in which the experiment is made; and he infers that the difference is due to the influence of the gaseous substance interposed. It does not appear to me that he has sufficiently considered the fact, that the differences between the sparks in the experiments above represented and described, (e. 165, &c.) is the effect simply of the relative position and dimensions of the balls between which they pass. That it is not dependent on the nature of the electricity must be evident from the circumstance, that both the long and the short spark were produced by the positive excitement in the experiments adduced by me. (165, &c.)

*Electrical Brush.*

173. When the machine is in active operation, a prime conductor insulated, the electricity will be sent from a small knob attached to it, so as by the constant light to exhibit the form of a luminous brush, presented at B, in the adjoining figure. For the production of this phenomenon, it is necessary that the fluid shall be condensed into a small prominent mass, agreeably to the preceding explanation, to have penetrating power. This it cannot possess, when, with the same intensity in the generating power, a large, positively electrified. In that case, the electric fluid presents a front too broad to procure a passage through surrounding non-conducting air. A small ball, negatively electrified, can only be productive of a diffuse attraction for the electric matter in the atmospheric medium around it; so that it has less ability to exert any penetrating power, than when acting upon the electricity in a comparatively large globular conductor, as in the preceding illustration. When the knob is on the negative pole, it may be productive of a similar appearance in its immediate vicinity, where the electric matter, coming from the adjoining space, becomes sufficiently intense to be productive of light; but it does not produce the striking appearance of the luminous brush.

174. As, agreeably to Du Fay's theory, the knob, whether vitreous or resinously electrified, is surcharged with an electric fluid, the penetrating power ought to be as great in the one case as in the other; and the spark and the brush should be producible in either case.

175. It has been mentioned that Faraday has of late endeavoured to show that the difference between the forms of the positive and negative sparks is greater or less, according to the gas through which they may be made to pass. An analogous change is also alleged by him to be produced in the forms of the positive and negative brushes, which are alleged to vary in their colour, and in their dimensions, with the nature of the gas within which they may be produced.

*On some Inferences from the Phenomena of the Electric Spark, contained in a recent Work on Heat and Electricity.*

176. In his valuable work on heat and electricity, Dr. Thomson has shown that if a long spark be taken between two knobs, as when severally attached to the positive and negative conductors of the electrical machine, the portion of the spark near the positive knob exhibits all the characters of positive electricity, while the remaining portion, proceeding from the other knob, displays all the characters of negative electricity. Although the learned and ingenious author does not state what differences there are between the different portions of the spark, and wherefore, if any, exist, he can, without a *petitio principii*, assume that they are such as to justify his conclusion, he proceeds to allege that there can be no doubt that the spark consists of two electricities; which, issuing severally from the respective knobs, terminate their career by uniting at the non-luminous portion of the spark, which is at a distance from the negative knob of one-third of the interval. Upon these grounds he infers that the positive electricity occupies two-thirds of the length of the spark, the negative electricity the third.

177. I presume, agreeably to the theory which supposes the existence of two fluids, that, when the equilibrium between oppositely excited sur-

restored by a discharge, whether in the form of a spark or otherwise, there must be two jets or currents passing each other; the one conveying as much of the resinous as the other does of the vitreous electricity. Of course no part of a spark can be more negative than it is positive, nor more positive than it is negative. Upon this ground, a suggestion of the same author that the diminution of light near the middle of the spark results from the combination of the different fluids at this point, appears to me objectionable; since there is as little ground for supposing the union of the fluids to take place there as elsewhere. But admitting that the union does take place as supposed, is this a reason for the observed diminution of light? If, when isolated, either fluid is capable of emitting a brilliant light, should not their co-operation increase the effect?

178. In deflagrating, by voltaic electricity, a wire of uniform thickness, equally refrigerated, the most intense evolution of heat and light is always midway.

179. In truth, the theory which the learned author sanctions, requires two postulates so irreconcilable, that unless one be kept out of view, the other cannot be sustained. It requires that the fluids should exercise an intense reciprocal attraction adequate to produce chemical affinity, and of course, enter into combination when they meet, and yet rush by each other with inconceivable velocity, not only through the air, but also through the restricted channel afforded by a small wire. If the fluids combine at a point intervening between the surfaces from which they proceed, what becomes of the compound which they form? Is it credible that such a compound would afford no indication of its existence? But, again, how are two surfaces, the one previously deprived of a large portion of the negative electricity naturally due to it, the other made as deficient of the positive fluid, to regain their natural state? By a combination midway, the resinous and vitreous surcharges might be disposed of, but whence could the vitreous and resinous deficiencies be supplied?

180. Dr. Thomson, in common with the great majority of modern chemists, ascribes chemical affinity to the attraction between the two electricities combined with ponderable particles. As the combinations between such particles take place only in definite proportions, would it not be consistent that the fluids which give rise to them should combine agreeably to those laws? But if the electrical compound, formed of the vitreous and resinous electricities, be decomposable by induction, as the theory in question requires, its constituents must be capable of uniting in every proportion.

181. Agreeably to the late investigations of the celebrated Faraday, equal quantities of the electric fluid are evolved, by analogous chemical changes, from equivalent weights of different ponderable bodies. It may, therefore, be inferred, that in entering into combination, the electric fluid is obedient to those laws of definite proportion which regulate other substances.

#### *Illuminated Globe, Pane, and Tube.*

182. Little disks of tin foil are so pasted in succession on a glass globe, pane, or tube, as to leave only a minute interval between them. In consequence of this arrangement, when situated in the circuit between the poles of an electrical machine, the electric fluid, availing itself of the conducting power of the metal, and leaping over each interval, produces as many sparks as there are intervals. At the same time, if these intervals fall within the lines of any drawing, the image representing the drawing will appear at each flash; and when, as in using a large machine, the flashes are almost incessant, the effect upon the eye is nearly as permanent as if the illuminated spaces were inherently luminous.

Fig. 1.



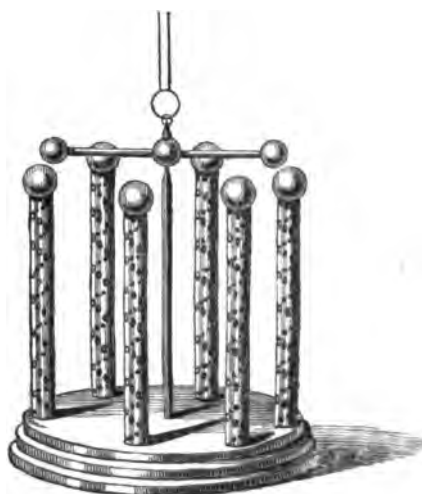
Fig. 2.



183. In the case of the globe and tube, represented by figures 1 and 2, are arranged in spirals, winding about the globe or tube from one apex or the other. However intricate the route which ingenuity may, by means of the foil, prescribe, it will be pursued by the fluid with fidelity, when the air and dry. Yet the sum of the intervals must not exceed the whole striking distance of the machine, or in other words, the greatest length of its spark.

184. This illustration may be varied by means of apparatus, of which several descriptions will be found in the two following articles.

### *Illuminated Columns.*

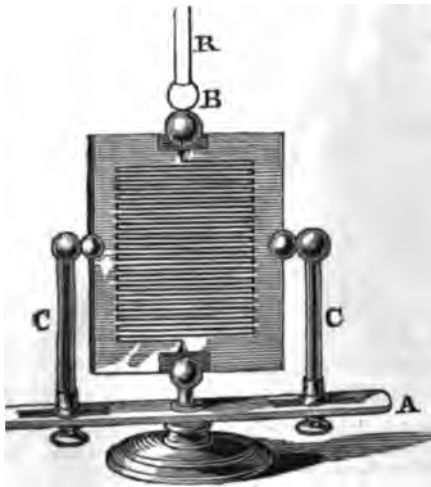




35. A swivel of wire, terminating in knobs, is so balanced upon a pivot, that, when charged, it revolves from the brass knob of the column to which it is nearest, that of the next, and thus successively conveys to each the sparks imparted to it by the machine.

*Carreux Etincelantes.—Sparkling Panes.*

36. This appellation is given in Pixii's Catalogue to the apparatus described in following article.



187. This figure represents a pane, in which the discontinuities in the tin foil attached, as explained, (s. 182,) being made to occur along the lines of a drawing, an image is seen as often as the electric spark passes. The frame, A, having two glass columns surmounted by metallic clasps for securing the pane, is contrived to accommodate a succession of panes, all of one size exactly, on which different images are delineated, and which may be shown in succession. In operating, the upper ball, B, is situated so as to be in contact with the sliding rod, R, of the prime conductor. At this point, the fluid enters, and coursing horizontally, first towards one side, and then towards the other, it finally escapes at the other ball into

foot of the instrument, which should communicate with the cushions of the machine, directly or indirectly.

*Illuminated Eggs.*



188. Between three glass columns a pile of eggs is supported in mutual contact. They are also in contact at top and at bottom with spiral wires; in the one case communicating with a chain, in the other, with a brass knob which surmounts the cap in which the columns terminate, and by which they are secured. The eggs thus situated may be taken into the circuit between the conductors of the machine, or the coatings of a battery, and thus be illuminated by the passage of the electric fluid. The experiment is seen to the best advantage when a powerful machine is employed, as the effect is in that case durable; scarcely any intermission taking place in the flashes. The contents of the eggs appear to be exposed to the eye, as if divested of their shelly covering.

*Electric Light in Vacuo.—Aurora Borealis.—Shooting Stars.*



189. The appearances of the electric fluid, when in the act of passing from an insulated conductor intensely excited; or during its efflux, or during charging and discharging of coated surfaces, has been sufficiently illustrated &c.) When an electrical discharge takes place within a cavity, from which air has been exhausted by an air-pump, the form assumed is much more difficult the brilliancy of the light is proportionably diminished. Moreover, the space through which the discharge can take place, is prodigiously greater. It is of an apparatus which the adjoining figure represents, that I am accustomed to exhibit the passage of electricity through an exhausted receiver. After being sufficiently removed by the air-pump, it is only requisite to make a communication between the excited prime conductor of the machine (see 21) and the receiver, which passes through the cap, as represented in the figure, in order to have the most beautiful coruscations, resembling in miniature those of the aurora borealis. I am confident that this meteor is the effect of electrical discharges, as that arises from that cause. I conceive that such discharges take place not only of the terrestrial poles, rendered electric by frost, into the rare medium of only a few miles above the earth's surface, (see 21) but also from one planet to another. I will venture even upon the bold suggestion, that discharges may take place not only from one planet to another, but even from the sun, or solar system, to another. Since it has been shown by Wheatstone, that the velocity with which electricity can be transmitted through a perfect conductor is not less than that with which light is projected from the sun, wherefore should it be unreasonable to conjecture that the former, in order to preserve its equilibrium, should pass through distances commensurate with those through which the sun is known to radiate?

190. I think it highly probable that the shooting stars of November 13 were caused by the afflux of an immense quantity of electricity to our planet from some other planet, or from some remote part of space.

191. It may be said that the passage of light is now generally ascribed to undulations of an intervening ether. I would in the first place observe that it remains to be shown that a discharge of electricity is not due to the progressive motion of an intervening imponderable fluid.† Besides, if the passage of light

\* In order that numbers referring to the new edition of the Compendium be distinguished from those referring to this treatise, the latter will be preceded by the letter s.

† See my Treatise on Electro-magnetism, page 79.

particles, from the most remote of the visible stars, was not deemed an objection to the Newtonian theory of light, wherefore should there be any difficulty in making a transfer of electric matter to be productive of an aurora or shooting star? It appears to me that the ordinary luminous appearances which we call fall-lights, may be the effect of electrical discharges upon our planet, which become visible as they enter the terrestrial atmosphere.

### *Of Electrical Ignition.*

#### *Ignition of Cotton by the Electric Spark.*



193. Let one of the knobs of a discharger be surrounded by a tuft of carded cotton, containing as much finely powdered rosin as it will retain; and while the other knob touches the outer coating of a Leyden jar properly charged, let the cotton be approximated to the knob proceeding from the inner coating of the jar. A spark will pass, and the cotton will be ignited.

#### *Inflammation of Ether by the Electric Spark.*

194. This object is conveniently effected by means of a wine glass with a perforated stem, through which a wire passes from a disk of metal cemented to the foot. The wire rises about two-thirds of the height of the glass, terminating in a knob. Up to the middle of the knob, the cavity of the wine glass may be filled with plaster of Paris, or other cement, so as to leave only

a portion of the knob bare. The ether should form a thin stratum not entirely covering the apex of the knob.

195. In consequence of its ready vaporization and admixture with air in open vessels, ether is always surrounded by an explosive atmosphere which is readily inflamed by the passage through it of an electric spark, either from the conductor of a machine, or from a Leyden jar. The result is rendered more interesting, when accomplished by a discharge from surfaces electrified by means of water. (c. 93.)

#### *Ignition of Hydrogen with Oxygen.*



by means of a wire, insulated by being enclosed in a glass tube cemented in a socket, which screws into the touch-hole of the little cannon above represented,

a spark from an excited conductor may be made to cross a small interval within the bore of the piece. Hence, if an explosive gaseous mixture of hydrogen with oxygen, or atmospheric air be made to occupy the cavity, and be secured by a cork, the mixture will explode on presenting the knob, K, of the insulated wire, to the prime conductor of the machine when in operation. It may be fired by the finger, or the nose of a person supported upon an insulated chair or stool, and commencing at the same time, with the prime conductor sufficiently excited.

### *Of the Electrical Shock.*

197. This effect of the electrical fluid is subsequently treated of in illustrating the mode of electrifying a patient.

### *Of Mitigating the Effects of Electricity.*

198. The same charge of electricity, which would produce a shock or deflagrate a wire if received through a knob, may be received imperceptibly through a fine point. The power of an electrical machine, or that of a large battery is thus easily paralyzed. Hence the employment of pointed rods of metal as a protection against lightning. Hence, also, it is necessary, in the construction of electrical apparatus, to avoid all edges or acute projections, unless where it is intended to facilitate the passage of the fluid.

199. *Rationale.*—When a knob is approached to an excited conductor, as soon as any portion of it is near enough to be struck, so much of the ball is at hand as to allow the whole discharge to take place at once; but when the apex of a pointed wire is near enough to receive a portion of the fluid, the other parts are too remote to come into action; and whether the point advances to the electrified body, or the body approximates the point, the fluid is discharged before it is within striking distance of the thicker part of the wire.

200. In fact, the difference between a discharge by a point, and through a knob, resembles that which exists between making an auger-hole in a reservoir to let out a fluid, and opening a floodgate.

### *Of the proper Mode of constructing and putting up Lightning Rods.*

201. The competency of pointed rods to protect us against lightning is dependent, not merely on the excellence of the point, which should be of platinum, but on the

de in which the joints in the conductor are made, and the nature of the soil in which it terminates. If a wire, pointed at one end, be blunt at the other, and the nearest conductor to the blunt end be not pointed, the charge will not pass off gradually because received at a point. Moreover, the power of a conductor to receive the electric fluid is compounded of its own conducting power, and that of the medium in which it terminates.

202. A metallic rod, terminating in a glass handle, in masses of sulphur or resin, or in dry sand, would not operate as a conductor. It cannot receive electricity, because it cannot deliver it.

203. Moist earth is but an imperfect conductor; since it owes its faculty of conducting to water, which, according to Cavendish, conducts with 200,000 times less facility than iron.

204. Lightning rods should, therefore, be connected, by soldering, with an extensive metallic surface buried under the earth; as, for instance, with sheets of lead or copper.

205. The cases in which conductors have been found incompetent, are, I am satisfied, referrible to their inadequate communication with the earth.

206. Thus is an important lesson given with respect to the means of protection against lightning. In vain do we employ for this purpose a conductor, however perfect, if it have communication with the earth only through a limited contact with the soil, which, being at best an imperfect conductor, may become an electric by desiccation.

207. I have surmounted the lightning rod by which my mansion is protected, by 17 copper wires pointed at one end, and at the other soldered into a hole drilled in the wall, which is constructed of iron. The juncture is surrounded by a globe of zinc of about two inches in diameter; above which the wires extend divergingly. The copper wires, by their association with zinc, are protected from oxidation; while their greater fusibility, as compared with the platinum point usually employed, is compensated by their number. The rod thus mounted rises about 10 feet above the apex of the roof, to the copper covering of which its lower end is soldered. The copper covering has a ample metallic connexion with the pipe for carrying off the rain, and this pipe with those of the public water works; all the joints being made with screws or solder. By these

means a most ample communication with the earth is obtained. Analogous means should be employed in the case of all lightning rods, in situations where access can be had to a similar ramification of metallic pipes.

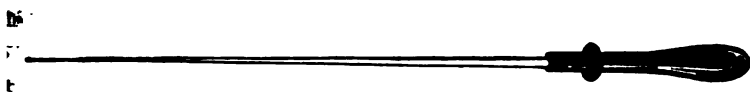
*King's Improvement in the construction of Lightning Rods.  
Expedient suggested by the Author.*

208. Since the preceding suggestions were made, I have become acquainted with the plan of putting up lightning rods, pursued by King, an ingenious practical electrician of Boston. Agreeably to this plan, in lieu of round iron square copper rods are employed, the corners being made as jagged as possible, by cutting them with a cold chisel so as to cause them to resemble rude irregular saw-teeth. By these means it was conceived, and with reason I think, that if a discharge should be made through the rod greater than it could convey to the earth, the excess would be dissipated in the air, in preference to entering a house in order to find a conveyance through the imperfect conductors of which buildings are constructed.

209. This ingenious innovation has led me to contemplate an expedient in which I have great confidence. It would extend the rod forming the conductor, underground, to a tree or post, at the distance of from fifty to one hundred feet, and cause it there to terminate in a band of copper, of which the edge should be so cut as to resemble large saw-teeth. These should be bent out in such a manner as to project horizontally from the band, at a distance of not more than six inches from the surface of the ground. It will, I think, strike any experienced electrician, that by means of such a serrated band of copper as I have described, the electric fluid would be dissipated into the air, and over the surface of the ground, with facility so great, as to prevent it from leaving the conductor for any other channel in which it might do mischief. The portion of the conductor under ground, should consist of copper, but I think that a wire of  $\frac{1}{4}$  inch in diameter would be sufficiently large for that portion.

*Experimental Illustrations.*

210. Effect of a point shown in drawing a charge from a battery or conductor:—proved, also, that its power

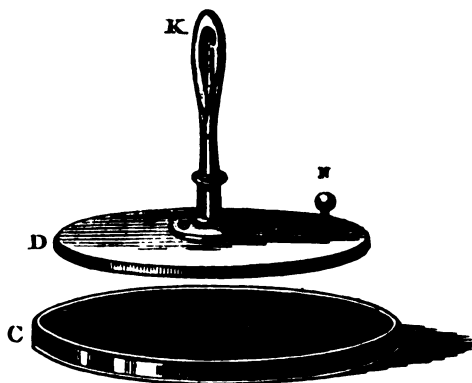


weakened or destroyed by being associated with an electric or imperfect conductor.

#### ADDITIONAL MEANS OF PRODUCING ELECTRICITY.

*Of the Electrophorus.—Of Electricity evolved by the Friction of Caoutchouc.—Of Electricity evolved by Pressure.*

#### *Of the Electrophorus.*



211. This is a peculiar instrument for the excitation of electricity, which we owe to the celebrated Volta. Electrical induction has already been explained (e. 107, &c.); likewise the susceptibility of resinous substances to be electrified negatively by friction has been illustrated. (e. 3, 33.) The electrophorus is indebted for its efficiency to the cooperation of the effects of friction with the inductive power. By rubbing the cake of resin, C, with the fur side of a dry cat skin in a dry atmosphere, the resin is negatively electrified. If the metallic disk, D, be placed upon the resin while thus excited, it will acquire a greater capacity to receive electricity, in consequence of the proximity of the negatively excited surface of the resin, as has already been explained in the instance of the condensing electrometer. (e. 127, &c.) Hence, if placed upon the resin with the aid of the glass handle, K, on applying the knuckle to the knob, N, a spark will pass, and again when

the disk is lifted about an inch or two from the resin, another spark will be received; and this may be continued in a dry air for a longer time than any operator would have patience to repeat the operation. In dry weather, and in a dry apartment, an electrophorus will give sparks for many weeks, without being again excited by friction. It was through the aid of this property of his electrophorus, that Volta was enabled to contrive an apparatus for the production of instantaneous light, of which an engraving and description will be found in the Compendium, (327, &c.)

*Of Electricity evolved by the Friction of Caoutchouc.*

212. Dr. J. K. Mitchell has ascertained that in the surface of a bag made of caoutchouc, or that of a thin sheet of the same material stretched on a frame, there is a surprising susceptibility of electric excitement. The attractive power, consequent to the excitation, appeared to me peculiarly powerful.

*Of Electricity evolved by Pressure.*

213. There are many substances, especially gum elastic or caoutchouc, which, if placed upon the disk of an electrometer, and pressed, will, on the cessation of the pressure, evolve enough electricity to be indicated by the gold leaf.

*Evolution of Electricity from Caoutchouc by Pressure.*



214. C, cap of electrometer; D, handle of metallic disk, between which, and the cap of the single leaf electrometer, may be seen a piece of caoutchouc subjected to pressure. The disk being suddenly removed, the leaf will strike the ball as when otherwise electrified.

THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.

215. It may be proper to give the rationale of the production, accumulation, and neutralization of electricity, agreeably to the doctrine of two fluids.

216. This doctrine has, within the last thirty years, been gaining credit, especially on the continent of Europe.

*Of the Theory of two Fluids.*

217. According to this hypothesis, when a body is electrically excited, a neutral compound, formed of two electrical fluids, is decomposed; one acc-



lates in the excited body, the other is evolved. That which accumulates excited glass is evolved by excited resin; and vice versa, that which accumulates in resin is evolved by glass. Hence, according to this theory, two electricities are always produced both by resin and glass; though fluids accumulated in them respectively, being, in the first instance, separately recognised and associated with the substances in which they are observed, were named accordingly.

218. When, as in an electrical machine, a portion of the surface of a glass cylinder or plate is rubbed against a cushion, it gives off resinous and evolves vitreous electricity. This surcharge of the vitreous fluid is removed by the excited surface, until, in revolving, it comes opposite to the collector. (c. 21, 28.) The change of capacity, which caused the glass to reject the resinous and attract the vitreous fluid, ceasing with the friction to which it owes its existence, an equalization of the electricities between the glass and the conductor, through the collector, ensues; by which the excitement is reduced, more or less, according to the extent of the respective surfaces. Returning to the cushion, the glass is re-excited to the same extent as at first; and, by a continuation of the process, gradually causes

an exchange of vitreous for resinous electricity between the conductors, until they are electrified as oppositely as the performance of the machine will permit.

219. Under these circumstances, if a conducting communication be made between the oppositely excited bodies, the electricities rush together, neutralise, and a total cessation of electrical phenomena.

220. By some philosophers, the union of the two fluids is supposed to be productive of the evolution of heat and light. The inevitable consequence of separating, they must absorb those elements, seems not to be sufficiently contemplated; nor indeed justified by any observed refrigeration between the surfaces of the cushion and electric, where the separation takes place. (c. 29.)

221. In charging a Leyden jar, the two coatings become, for the time they are in communication with the conductors, respectively a part of them. That which touches the resinous or negative conductor, therefore, gives up its vitreous electricity, and receives resinous; while an opposite exchange of resinous for vitreous takes place in the other coating. Meanwhile, the opposite electricities are supposed to exercise a reciprocal attraction through the glass, and are thus retained upon the surfaces which they respectively occupy. Of course a removal of the coatings does not cause a removal of the charge.

222. When the positive and negative surfaces of a charged pane act simultaneously on a metallic arch made to complete the circuit between them, the resinous electricity is attracted out of the end of the arc, near the coating vitreously charged, while the opposite effect takes place at the other end. Thus, by a series of decompositions and recompositions, or by currents passing each other, the different surfaces are restored to their previous state.

223. The principle of induction is much resorted to, agreeably to the doctrine of two fluids, to explain the passage of a spark between a body either vitreously or resinously excited, and one which is neutral. It is supposed that the fluids attract each other in all proportions, and in a way to bring into equilibrio the self-repellent power of the homogeneous atoms tending to dissipate the aggregate fluid, and the attraction of the heterogeneous atoms tending towards its accumulation. Yet it is conceived that

the equilibrium is liable to be destroyed by the presence of a body charged with either electricity. If it be vitreous, by induction it repels the vitreous fluid from any mass in its vicinity, and attracts the resinous; if the surcharge be resinous, it repels resinous electricity, and attracts vitreous. When this species of reaction reaches a certain degree of intensity, the surcharge, and the heterogeneous electric matter, which, by the induction process, has been accumulated in the neighbouring conductor, rush together, producing an electric discharge, and under favourable circumstances a spark or a shock.

224. Thus the unknown electric compound, formed by the union of the two electricities, is considered as liable to be decomposed by the proximity of either of its constituents in excess.

225. When of two portions of the same matter, one is remote, the other actually combined with a common object of attraction, I cannot understand wherefore the one should be displaced by the other.

#### *Additional Remarks explanatory of Franklin's Hypothesis.*

226. According to the theory of Franklin, the effect of an electrical machine in drawing electricity from the cushion, and accumulating it in the prime conductor, has some analogy with that of a wheel or pump forming water.

227. The increased capacity for the electric fluid, arising from friction in the glass, operates like a bucket on a wheel, to enable it to receive a portion of fluid; and the loss of this capacity, after the friction ceases, is analogous to that inversion of the buckets which causes them to be emptied at every semi-revolution.

228. When the liquid thus raised is withdrawn from one reservoir to be thrown into another, so that the quantity in the former is diminished as much as it is increased in the latter, the effect is analogous to that of the cylinder or plate of an electrical machine in creating a surcharge in one of the surfaces of a pane at the expense of the other. Should the reservoirs be allowed subsequently to communicate by a syphon or sluice, and in consequence being on the same level, a previous equilibrium of pressure be restored, the office performed by the syphon would be analogous to that of a metallic arc in restoring the electrical equilibrium of the charged surfaces of a coated pane; excepting that the velocity of the electric current is incomparably greater.

229. In explaining the operation of charging a coated pane by the theory of Franklin, the incessant agency of the attraction between the fluid and the glass should be kept in mind. It is necessary to suppose an intense attraction to exist between the glass and the electrical particles; while between these particles there is an intense self-repulsion. When these forces are unimpeded, there can be no electric accumulation, because operating equally, they must produce an equal distribution of the electric fluid.

230. In a charged pane, this tendency to an equilibrium is counteracted by the impermeability of the glass, so that when by the operation of the machine, the fluid is abstracted from one side of the pane to be piled upon the other, the same attraction of the glass which resists the withdrawal of the fluid from the negative surface, retains it upon the positive surface as soon as it reaches it; while the surcharge thus retained, prevents any accession to the negative surface of electricity from other bodies. Thus an electrical surcharge in a coated jar or pane, is dependent on its attraction for the

gative surface, and the repulsion between it and the electrical matter in her bodies.

231. In concluding this theoretic explanation, I refer the reader to some suggestions in my letter to Faraday, which are quoted at the close of my treatise on Electro-magnetism, page 77.

### *Rationale of Electric Light and Ignition.*

232. It appears evident that there is a re-action between heat, light, and electricity.

233. It is not surprising, therefore, that the presence of one should cause the appearance of either of the others; since they all, evidently, pervade nature. It may be conjectured that the electric fluid is luminous when projected with intensity into the air, in consequence of its carrying along with it the light encountered in its progress through ponderable matter. In like manner it may cause the excitation of caloric, by displacing it when latent; or by adding temporarily to its repellent power, it may enable it to overcome the attraction of cohesion; in which case metal, no doubt, contains caloric enough to produce a violent, or even explosive separation of the metallic particles. (Compendium, 274, 275.)

234. It has been mentioned that, agreeably to the late researches of Faraday, the electrical spark varies both as to its dimensions and shape, with the gas employed as the medium for the experiment.

235. "In nitrogen, it is alleged to have been found pre-eminently beautiful, having still more of the purple hue than in air." "In oxygen the sparks were whiter than in air, or nitrogen, but less brilliant." "In hydrogen they had a fine crimson colour not due to its rarity," since rarefaction diminished this characteristic. "In carbonic acid the spark was similar to that in air, but had a little green in it. The sparks were remarkably irregular in form, more so than in common air, and could be obtained longer, under the same circumstances, as to size of ball." "In muriatic acid the spark was bright throughout, and nearly white, never presenting any dark parts as in air and some other gases." "In coal gas the spark was sometimes green, sometimes red, and occasionally one part was green and another red." "These varieties of character," says the distinguished author, "impress my mind with a feeling that they are due to a direct relation of the dielectric, through which the discharge occurs, and are not mere results of the casual ignition or secondary kind of action of the electricity upon the articles which it finds in its course."

236. From the facts cited above, it must be evident that a specific influence is exerted, by gaseous substances, upon the form, dimensions, and colour of the electric spark; and from some paragraphs which I subjoin, this appears to be equally true as respects the brush; yet when the diversity of colour produced by different substances, by reflection or transmission; also from their combustion, or from their mere presence, as in the case of stron-

tia (1493), when no chemical change is experienced or induced, it does not appear to me that the variations in the hue of the light emitted, affect the plausibility of the rationale given above by me.

237. *Air*.—Fine positive brushes are easily obtained in air at common pressures, and possess the well-known purplish light. When the air is rarefied, the ramifications are very long, filling the globe; the light is greatly increased, and is of a beautiful purple colour, with an occasional rose tint in it.

238. *Oxygen*.—At common pressures, the brush is very close and compressed, and of a dull whitish colour. In rarefied oxygen, the form and appearance are better, the colour somewhat purplish, but all the characters very poor compared to those in air.

239. *Nitrogen* gives brushes with great facility at the positive surface, far beyond any other gas I have tried: they are almost always fine in form, light, and silent, and in rarefied nitrogen are magnificent. They surpass the discharges in any other gas as to the quantity of light evolved.

240. *Hydrogen*, at common pressures, gave a better brush than oxygen, but is not equal nitrogen; the colour was greenish gray. In rarefied hydrogen, the ramifications were very fine in form and distinctness, but pale in colour, with a silken velvety appearance, and not at all equal to those in nitrogen. In the rarest state of the gas, the colour of the light was a pale gray green.

241. *Coal gas*.—The brushes were rather difficult to produce, the contrast with nitrogen being great in this respect. They were short and strong, generally of a greenish colour, and possessing much of the spark character: for, occurring at both the positive and negative terminations, often when there was a dark interval of some length between the two brushes, still the quick, sharp sound of the spark was produced, as if the discharge had been sudden through this gas, and partaking, in that respect, of the character of a spark. In rare coal gas, the brush forms were better, but the light very poor and the colour gray.

242. *Carbonic acid gas* produces a very poor brush at common pressures, regards either size, light, or colour; and this is probably connected with the tendency which this gas has to discharge the electricity as a spark. In rarefied carbonic acid the brush is better in form, but weak as to light, being of a dull greenish or purple hue, varying with the pressure and other circumstances.

243. *Muriatic acid gas*.—It is very difficult to obtain the brush in this gas at common pressures. On gradually increasing the distance of the rounded ends, the sparks suddenly ceased when the interval was about an inch, and the discharge, which was still through the gas in the globe, was silent and dark. Occasionally a very short brush could for a few moments be obtained, but it quickly disappeared. Even when the intermitting spark current from the machine was used, still I could only with difficulty obtain a brush, and that very short, though I used rods with rounded terminations (about 0.25 of an inch in diameter) which had before given them most freely in air and nitrogen. During the time of this difficulty with the muriatic gas, magnificent brushes were passing off from different parts of the machine into the surrounding air. On rarefying the gas, the formation of the brush was facilitated, but it was generally of a low squat form, very poor in light, and very similar on both the positive and negative surfaces. On rarefying the gas still more, a few large ramifications were obtained of a pale bluish colour, utterly unlike those in nitrogen.

#### MEANS OF ELECTRIFYING PATIENTS EITHER WITH SPARKS OR BY SHOCKS.

##### *Electrifying with Sparks.*

244. A person, seated on an insulated chair, is made to communicate with one of the conductors. Being thus negatively or positively electrified, sparks may be taken from any part of the body, by a metallic knob or point. If the sparks emitted by the knob be too severe, the point may be used; and if the current from this be too powerful, it

be covered by a wooden cone, C, represented in the following engraving.



*Apparatus for Electrifying by Shocks.*



245. In order to subject a person to shocks, a coated jar is used with two knobs; one in communication with the inside coating through the rod, R, which supports it, the other supported on an insulated wire, W, so that it may be made to approach or recede from the knob which communicates with the inner coating. To the outer coating of the jar the insulated knob, chains are attached, each terminating at one end in a knob of metal with an insulating

handle. The handles are held by the operator, and knobs applied to the patient, so as to leave between the part to be electrified. The coatings of the jar being severally connected with the different conductors of the electrical machine, the charge increases in the jar until it becomes strong enough to strike through the interval between the knob connected with the inner coating, and that insulated in its vicinity. Of course, the height of the charge depends upon the interval thus left, according to the operator's discretion, or the feelings and fortitude of the patient.

# OF GALVANISM,

OR

## VOLTAIC ELECTRICITY.

---

300. As to the nature of the cause of electrical phenomena, there is a great and mysterious uncertainty. By a majority of electricians, Dufay's suggestion of the existence of two fluids is sanctioned (E, 217, &c.\*), while, by others, Franklin's idea of one fluid is preferred; yet philosophers of high pretensions question the existence of any imponderable matter. Whewell, of the University of Cambridge, England, published an essay a few years since, of which it was the object to prove, that "all matter is heavy." Faraday, so highly distinguished by his Herculean researches, advanced the idea that electrical induction is the consequence of an action of contiguous ponderable particles; not an affection arising from their association with imponderable matter. In letters published in Silliman's Journal, I consider myself as having invalidated the positions thus taken by these eminent philosophers.

301. Nevertheless, I find it necessary to abandon the idea that there is any transfer of imponderable matter during electrical discharges. Latterly I have conjectured, that electrical phenomena are due to the opposite polarization of electric matter, which pervades all bodies and all space; so that the two electricities are the effects of the same matter in different states of polarization, and an electric current consists of a succession of polarizing impulses. On this subject I shall return when the facts on which this inference is founded shall be the subject of consideration.

302. Nevertheless, it seems universally to be deemed expedient to suppose, provisionally, the existence of fluid electric imponderable matter; and the movements of the current are more easy to conceive of and describe,

\* In referring to the numbers of paragraphs in this series, I shall prefix the letter E: in referring to my

see on "Electricity Produced," the letter C.

than those of two fluids, the language founded on Franklinian theory is much used, even by those who assume the existence of two fluids.

303. Consistently with the hypothesis of Dufay (E, 21) there must, in every part of any active electric circuit, two fluids flowing oppositely to each other. The quantity of either fluid must be increased as that of the other is diminished, so that there can neither be any diminution, nor any increase of the sum of the quantities of both fluids. Moreover, the current in an electric circuit can not be directed from positive to negative, than from negative to positive. Nevertheless, the terms positive and negative, or minus and plus, are applied to the states of bodies implying, of course, a deficiency in the one case, and a redundancy in the other. Moreover, arrows indicating current to move from the positive to the negative pole are almost universally used.

304. I shall employ, on all occasions, a language corresponding with the theory of Franklin, wishing it to be understood, that when employing the words *electrical current*, as designating the phenomena of an active galvanic circuit, I do not mean to convey the idea that those words are sufficiently descriptive or accurate. The words *electrical current* should rather be understood to designate an unknown cause of certain effects, which are in some respects such as might result from a current of imponderable matter.

*Of the Elementary Battery, or Simple Galvanic Pair, and its Circuit: more properly designated as a Galvanic Triad.*

305. It is generally known that metals are liable to what is called corrosion, arising from a reciprocal action or reaction, with certain gases or liquids; also, that some metals will react with liquids or gases, with which other metals will undergo no reaction.

306. It may be assumed as a general law, that when two metals are simultaneously exposed to a liquid, and combining with one of them a more energetic reaction takes place with the other, the phenomena will be such as to conform with the idea of an electrical current from the more susceptible metal, through the liquid, to the other metal:

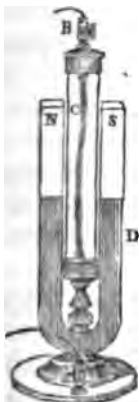


from this, through any competent conductor, back again to the first mentioned metal.\* To this result a complete circuit is indispensable; and it is on the completion of the circuit that the phenomena take place which are assumed to demonstrate a current. It is on this account that when the tongue is situated between a plate of copper and a plate of zinc, no sensation is perceived until the projecting extremity of one, touches that of the other: but as soon as his contact is effected, a discharge takes place from the zinc to the copper (or silver) disc, which affects the taste somewhat like a feeble acid. Where the surfaces are large, the current may be indicated by the ignition of a wire made the medium of communication, or by the attraction and polarization of iron filings; but among the most competent means of detecting such currents, is the galvanometer or multiplier of Schweigger. In this a magnetic needle, situated within a coil of wire as represented in figure 1, by its deflection detects the existence of the most feeble galvanic current, which may be made to pass through the coil by means of a wire communication with the ends, *a b*, of the wire.

Fig. 1.



Fig. 2.



307. Hereafter the reaction of the galvanoelectric current, so called, with the cause of magnetism, will be more fully brought into view, while at present it may be well to advert to another galvanoscope, which owes its existence to the same source. Fig. 2 represents this galvanoscope. When a small ribbon of gold leaf situated between the legs, *N S*, of the magnet, *D*, and parallel thereto, is made the medium of a minute galvanic discharge, the ribbon is swayed one way or the other, according to the direction of the current.

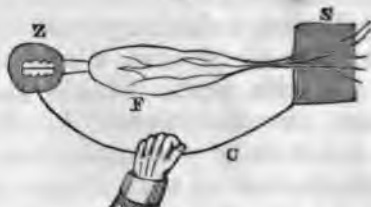
308. The tongue has been mentioned above as performing the office of a galvanoscope. Originally, the limb of a frog, with the lumbar or spinal nerves denuded, was employed by Galvani and his nephew, Aldini; and, recently, this organic instrument has been found by Matteucci, a distinguished modern in-

\* I here state the opinion generally held, yet Sturgeon alleges, that in the case of iron and amalgamated zinc, although the former is much the most rapidly dissolved, it nevertheless acts as copper.

vestigator, to be competent to the detection of a current too feeble to affect a most delicate galvanometer, of a construction analogous to that above illustrated.

309. The following figure will give an idea of a frog prepared so as to answer as a galvanoscope. The denuded lumbar nerves, with a portion of the spine attached,

Fig. 3.



are represented at *z*, the feet at *s*. Now, if *z* be a plate of zinc, and *s* a plate of silver, copper, or platina, on making or breaking the circuit by the metallic arch, *C*, convulsions will be produced. When the interruptions and renewals of contact at one of the extremities of the arch are rapid, the agitation is incessant.

310. When the frog is used as a galvanoscope, the metallic plates should be perfectly homogeneous, so as of themselves to produce no discharge. In lieu of resting on metallic plates, the nerves and feet may each be enveloped in tin, or such lead foil as is used in tea chests.

311. Thus prepared, a dissected frog may be included in any circuit, in lieu of the galvanoscopes above described. Under those circumstances, the passage of the most minute galvano-electric current will be indicated by a corresponding tremulous motion in the organic instrument employed.

312. When a galvano-electric current is produced by two metallic plates, or any other competent masses, and an interposed exciting agent, they are usually called a *galvanic pair*: but as three elements are requisite to the characteristic effect, I prefer to call the apparatus which they form, a *galvanic triad* (306).

313. In the construction of galvanic triads, various forms may be given to the metals upon which the liquid is made to operate; and any two metals will be productive of analogous results, provided that one be more susceptible of erosion by the exciting liquid than the other.

usually copper is employed, as combining in a preëminent degree, efficiently with cheapness. Yet silver would be preferable to copper, gold to silver, and platinum probably to gold.

314. It follows, that whatever may be demonstrated with respect to copper and zinc, will apply, more or less, in the case of other metals. Hence C and Z, the initials of copper and zinc, may be considered severally as representing two metals, one of greater, the other of inferior susceptibility of erosion. The electric relation of these metals may be changed by varying the exciting liquid. Thus, for instance, in a galvanic arrangement, in which copper and zinc should be subjected to ammonia, which acts upon copper more than upon zinc, the latter metal would, in a simple galvanic circuit, give electricity to the former. It appears, also, that in lieu of two metals and one liquid, we may employ two liquids with one metal; or one metal with one liquid may be employed, provided the surfaces be in a different state as to roughness, since a more powerful reaction takes place with the rougher surface.

315. The energy of the current varies also with the greater or less disposition of the negative, or less oxidizable metal, to become tarnished by oxidation, or depositions from the liquid, and of being partially dissolved and precipitated on the other metal. These evils are so great in the case of zinc and copper, as to cause a battery constructed of them, without any remedial contrivance, to lose almost all its efficiency, before the zinc is exhausted. The zinc becomes so completely coated by a mixture\* of its suboxide with metallic copper, that due access of the acid is prevented.

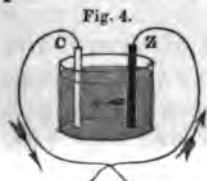
316. As either silver, gold, or platinum, differ from zinc more than copper does, as to liability to erosion, were it not for their superior costliness they would be preferable to this last mentioned metal. Platinum is preëminently preferable, being less susceptible of change than gold. A minute quantity of this metal, precipitated on the surface of silver or copper, has been found to make these metals

\* This mixture, after being softened by soaking in water, and then scraped off, I found, in one instance, to grow hot spontaneously. Probably this arose from a galvanico-chemical reaction between the moisture and the copper and zinc particles, during which these were acquiring an additional quantity of oxygen.

more efficacious in a galvanic triad, by diminishing the injurious tendency to coherence, between them and hydrogen. Recently it has been found, that either plumbago, coke, or the indurated carbon sublimed in vessels for evolving gas from bituminous coal, may be substituted for the copper in a triad.

317. From the phenomena of electrical fishes, and those observed by Matteucci in the muscles of frogs, fishes, and warm blooded animals, it is evident that the law, which has been assumed to be in operation in the case of metals, must prevail no less where organic substances are solely concerned (306).

318. Although at this stage of our illustration, any attempt to explain the theory or construction of the multiplier, or galvanometer, would be premature, it will be highly advantageous to employ it as the best means of detecting the direction and force of a galvanic current. At present, it will be sufficient to state, that when a galvanic discharge takes place through a wire, as from the copper plate C, to the zinc plate Z, both subjected to diluted acid,



as in fig. 4, the magnetic needle has a tendency to arrange itself, at right angles to the path of the current,\* and that consequently, if the current be made to pass parallel to the needle, a deflection in proportion to the quantity of fluid which

passes, will ensue. The interposition of the coil of the galvanometer, merely reiterates the influence of the current, by causing it to circulate many times about the needle. See Electro-magnetism, for various engravings and descriptions of this instrument.

319. The direction of the galvanic current is known from the manner in which the needle is deflected; since when the current is above, and flows in a direction parallel to the meridian, from south to north, the north pole is deflected so as to point westward, and of course the south pole, oppositely deflected, points eastward. When a similar current is flowing in the same direction below the needle, the deflection is the reverse of that just described:

\* More accurately, it may be said to take the attitude of a tangent to the circumference of a cylinder, in the axis of which the current flows.

but in any case, reversing the direction of the current, reverses the deflection.

320. In an elementary battery, or triad, consisting of copper, zinc and water, or any aqueous solution, the oxidation of the zinc is, as already suggested, indispensable to the production of the phenomena, which are conventionally attributed to an electrical current circulating from the zinc, through the liquid to the copper, and back again to the zinc. Under these circumstances, as the oxygen of the water combines with the zinc, it might be expected, that hydrogen, the other elementary ingredient of the liquid, would be liberated at the surface of the metal, as is known to be the fact, when zinc in an impure state, as found in commerce, is subjected to diluted sulphuric acid. But, in fact, so long as there is a metallic communication between the plates, the hydrogen will be liberated only at the surface of the copper. According to Faraday, there is no reaction and consequent evolution of hydrogen, when zinc, purified by distillation, is subjected, *per se*, to diluted sulphuric acid; nor from commercial zinc, if the surface be amalgamated, or in other words, coated by a film of mercury. The effect of this coating is to prevent the formation of local circuits, between the zinc and certain metallic impurities which it contains. A homogeneous substance is produced, which, *per se*, is scarcely susceptible of reaction with diluted sulphuric acid.

321. But although neither *pure* zinc, nor *impure* zinc when *amalgamated*, has, *per se*, any reaction with the water of diluted sulphuric acid, yet if touched by a piece of copper previously immersed in the solution, the oxygen of the water combines more or less with the zinc, while the hydrogen is copiously evolved from the cupreous surface.

322. This may be considered as another of the characteristic features of a galvanic circuit, though it cannot be so conveniently nor satisfactorily made manifest as the indications above cited (306, 307, 309).

323. The characteristic phenomena which have been described as resulting from a galvanic triad, are not inseparately associated with any particular forms of the generating surfaces, or arrangement of them. The same extent of superficies may be more efficacious when arranged in one way than in another, or may vary in its efficacy

with the energy of the exciting liquid; but whether either or both of the metals be used in one plate, or in several, does not alter the characteristic features of the circuit as they have been described.

### *Of the Calorimotor.*

324. In 1818 I contrived a modification of the galvanic triad or elementary battery, which I designated as a calorimotor or heat mover, under the idea that a current of heat no less than one of electricity, is an effect of the galvanic motive power.\*

325. The calorimotor consisted of twenty-one plates of copper communicating by a metallic strap, and twenty plates of zinc similarly associated, the plates of the one set being alternated between those of the other. In an apparatus thus constructed, the zinc is every where opposed by copper, so that both of its surfaces become equally efficacious. Still this apparatus, although consisting of forty-one metallic sheets, and twenty interstices complete with the exciting liquid, comprises only the three elements of a gal-

\* The ignition and deflagration of wires by the galvanic current has, by philosophers generally, been ascribed solely to electricity; the heat and light evolved having been treated as secondary effects. But as, agreeably to the observation of Davy, sanctioned by general experience, a finite portion of wire, exposed in the voltaic circuit, may be kept ignited for an unlimited time, it follows, that if heat be material, it cannot be supplied by the wire, and must be supposed to flow from the same source as the accompanying electricity. Considering the imponderable fluid put into circulation by galvanic reaction, as consisting of caloric as well as electricity, I inferred that the proportion of the caloric increased with the size of the pair, that of the electricity with the number; and that in a large apparatus of one pair, the latter fluid was in a minimum proportion, so that it was mainly caloric, which was made to circulate by a large galvanic pair which I had constructed.

It is demonstrated by the phenomena of *thermo-electricity*, of which an account will be given in due course, that a current of heat may be the primary cause of a galvanic current, in thermo-electric apparatus, just as much as a current of electricity is the cause of an evolution of heat from an apparatus, such as above described, called *hydro-electric*, because a liquid is requisite to the result. It seems, therefore, reasonable to consider, that both caloric and electricity may be products either of *galvano* or *thermo-electric* reaction; and that if heat be a secondary product in one case, electricity is no less so in the other. There is the most ample proof that the cause of the one, as well as of the other, exists in metals to an enormous degree. The arguments against the idea that a fluid is the cause of electricity, are, it seems to me, more difficult to answer than any that can be adduced against the existence of a material cause of calorific repulsion.

Contemplating a galvanic pair as simply a mover of the electric fluid, Volta had called such pairs, as existing in his series, *electromotors*. By analogy, I applied the term *calorimotor* to signify the large pair or heat mover above mentioned.

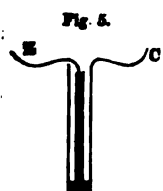
The opinion above alluded to, that the heat of an active galvanic circuit is not an electrical effect, as generally supposed, but that, on the contrary, caloric and electricity are connate and collateral products of galvanic reaction, was entertained when the causes, both of the calorific and electrical phenomena, were generally considered as material fluids, the electro-magnetic powers of the circuit in question being unknown. It will, in due course, be explained, that I am now disposed to consider the powers of the active circuit as the consequence of waves of polarization, and possibly of concomitant vibrations or movements, in one or more imponderable principles, which, pervading all space, are combined more or less in a condensed state with ponderable atoms, and enter enormously into the constitution of perfect conductors, in other words, metals.

But this view of the subject is entirely consistent with the inference, that heat and electricity are connate and collateral products of galvanic reaction, and that heat is no more an effect of electricity, than electricity is an effect of heat.

galvanic triad, one associated zinc surface, one associated copper surface, and the liquid interposed every where between them.

326. I ought to mention, that by means of a silver thimble, within which a minute piece of zinc was supported and insulated, Wollaston made an elementary battery capable of igniting a minute platina wire. In enlarging the size of the galvanic triad, as above stated, my course was diametrically opposite. Several methods of accomplishing this design occurred; among others, I contemplated concentric coils of copper and zinc, the former being so wound as to surround the zinc completely. Also, to unite several sheets of copper to one bar of metal, and several zinc sheets to another bar, the zinc and copper alternating. To the latter plan I gave the preference. Twenty sheets of copper, and a like number of zinc sheets, associated as above described, were secured in a wooden frame, so as to leave about a quarter of an inch between them. One end of a rope, passing over a pulley, was attached to the frame, while to the other end a counter weight was fastened. A cubical box of suitable size being placed under the frame thus suspended, and supplied with diluted sulphuric acid, the frame could be lowered into the acid liquid, or lifted out in an instant.

327. When one plate of zinc is placed between two of copper, as in the Wollaston elementary battery, represented by the adjoining cut, out of four



copper surfaces two are useless; but in a calorimotor where the same quantity of zinc is used so as to form several plates, say four, for instance, five copper plates of the same size, will be sufficient to constitute a calorimotor in which each zinc plate will be opposed by a cupreous surface, and only the outermost surfaces, the two external copper plates, will be useless. Hence, of the ten surfaces in the five copper plates, all but two are brought into action.

328. A battery, resembling the calorimotor in the alternation of surfaces, has lately been constructed, in which iron plates are made to perform the office of those of copper: much merit is attached to the construction, no reference being made to its previous employment by me.

329. While I was engaged in these experiments, Mr. Lukens, to whom I had mentioned the various plans which I had projected, of calorimotors, put into operation, with the aid of Dr. Patterson, the plan of concentric coils. Although this apparatus had less surface than that which I had constructed, and would not heat as large a wire as the latter, yet it communicated a much higher ignition to a small wire than mine was capable of producing.

330. Soon after this experiment of Patterson and Lukens, J. P. Wetherill, Esq., had a pair made in the form of concentric coils, of one hundred square feet of surface. From this great results were expected, and a large assemblage, of those interested in such experiments, attended to see the mammoth pair tried. But to the surprise of all present, it did not induce even a red heat in connecting wires, such as had been vividly ignited by my apparatus, or that of Patterson and Lukens.\*

\* Some time after these large pairs were constructed, similar apparatus was made by Mr. Pepys, of London, and likewise by Col. Offerhaus, on the continent; and although a memoir, in which I gave an account of these experiments, was published in *Silliman's Journal*, and in the *Annals of Philosophy*, Pepys' apparatus of concentric coils has been treated of as an original contrivance in *Turner's Chemistry*, and elsewhere. The apparatus of Offerhaus, though made long after those constructed

331. It struck me afterwards, that in a very large pair, the intensity not increase with the quantity of the fluid generated, since the impenetrable matter, or the waves of polarization, cannot be concentrated upon a given small point of afflux, as soon from a large surface, as from a small one.

332. It is analogous to the case of a small and a large stratum of

by Patterson and Lukens, and by Wetherill, was described as if it had been a form of apparatus.

Finding that in consequence of the low intensity of the current from my motor, consisting of one pair formed of two surfaces of fifty square feet, it did not produce a heat sufficient for the active deflagration of wires, I subsequently converted it into an apparatus of two pairs, the copper sheets of one alternating with the zinc sheets of the other.

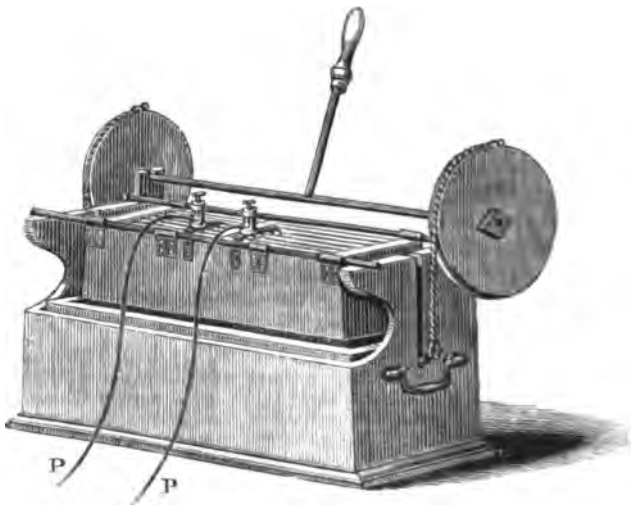
Two of the surfaces were united by a mass of solder. To the others were soldered, into which the ends of the wire were fastened, which was to be the medium of discharge. This form of the calorimotor I have found of great use, as a means of igniting gaseous mixtures in eudiometrical experiments, and other cases requiring ignition in close vessels.

Figure 5 represents a calorimotor of four pairs, so constructed that the dilute acid contained in a vessel of suitable form and size is brought into contact with the metallic surfaces, by applying the hand duly to the end of a lever associated with pulleys and two cords, attached severally to the ends of the vessel. The cords being wound up on the pulleys, raise the copper vessel so as to cause the acid to be immersed in the diluted acid.

The two forms of the calorimotor represented by fig. 6 and 7, have been used by me for what is described in my Compendium as "*galvano ignition*." Within any cavity, ignition of any intensity short of fusing platina may be produced by making a platina wire the subject of a galvanic discharge from an instrument of this kind. I first resorted to this process in the year 1820, for the purpose of igniting gaseous mixtures in eudiometers of various forms. In June, 1831, I applied it to gunpowder in rock blasting; and to this object it was subsequently recommended, agreeably to my recommendation, by Colonel Pasley, Professor O'Shaughnessy, and others.

**Engraving and Description of a Calorimotor of Four Pairs, or Triads**

Fig 6





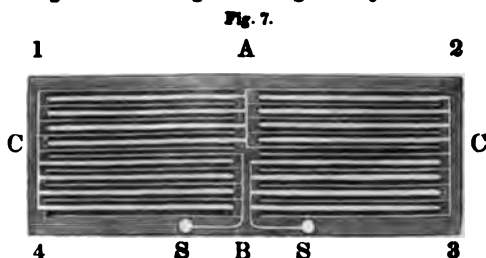
both of one depth. It is well known that the surface in both, being sustained at the same height above the points of efflux, a jet from the former stratum will go as far as one of the same diameter, emitted by the latter.

333. There was, however, one characteristic noticed by me, in which his analogy does not hold; I allude to the fact, that fine wire will not fuse when made the medium of discharge from a very large pair, although the same wire may be fused by a small one.

334. The capillary wire ignited by the thimble battery of Wollaston, could not be similarly ignited by a calorimotor of fifty square feet. I have mentioned that the coil of Patterson and Lukens ignited an iron wire about No. 24, more intensely than my larger apparatus of one pair, consisting of alternate plates.

335. Adopting the idea, that a current of electricity consists of waves of polarization, the mystery may be thus explained. The application of a wire to the electrodes, disproportionate in sectional area to the triad, the circuit of which it is employed to close, impedes the polarization of the greater part of the masses which enter into the construction of the triad. Hence the polarizable matter within those masses is prevented from attaining even that low degree of tension, of which one triad is susceptible when its circuit is completed by a competent conductor. It appears, therefore, reasonable to suppose, that the waves in a large calorimotor move less

*Diagram illustrating the arrangement of the Plates.*



This machine consists of sixteen plates of zinc, and twenty plates of copper, each twelve inches by seven, arranged in four galvanic pairs. The plates are supported within a box with a central partition of wood, A B, dividing it into two compartments. Each of these may be considered as separated into two subdivisions, by four plates of copper between the letters C C. Of course the box may be considered as comprising four distinct spaces, No. 1, No. 2, No. 3, and No. 4. The circuit is established in the following manner. Between the zinc plates of compartment No. 1, and the copper plates of compartment No. 2, a metallic communication is produced, by soldering their neighbouring corners to a common mass of solder, with which a groove in the wooden partition between them is filled. With similar masses of solder, two grooves severally made in the upper edges of each end of the box are supplied. To one of them, the corners of all the copper plates of space No. 1, and the zinc of space No. 4, are soldered. To the other, the zinc plates of space No. 2, and the copper plates of space No. 3, are soldered in like manner. Lastly, the zinc plates of No. 3 are connected by solder in a groove, and the copper plates of No. 4 are in like manner connected by solder in another groove. Upon the ends, S S, of the solder just mentioned, the gallews screws are severally soldered, and to these the rods, P P, called poles, are fastened. The means by which the acid is made to act upon the plates, must be sufficiently evident from inspection. Depressing the handle causes the wheels to revolve, and thus, by means of the cord which works in their grooved circumferences, to lift the receptacle which holds the acid, until this occupies the interstices between the plates.

The rationale of the increase of intensity resulting from the above described construction, will be given under the head of *compound circuits*.

speedily, while they have, on the average, much further to go than those created in comparatively minute apparatus, essentially of the same construction.

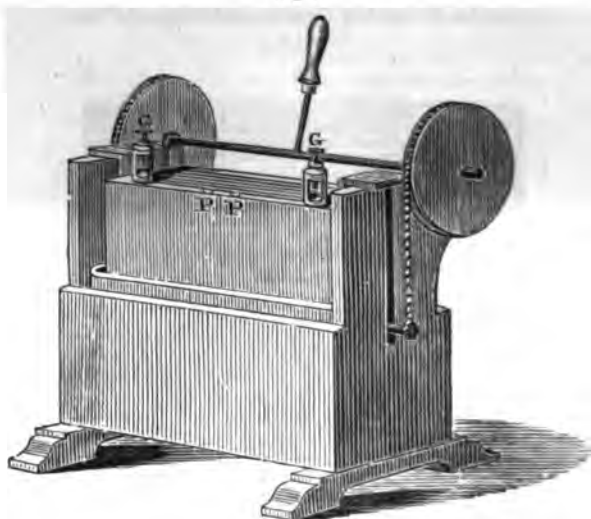
336. There seems to be an analogy between the part performed by a conductor in completing a galvanic circuit, and that of a keeper in completing the circuit of a magnet so far as this; that in either case, the help by which the completion is accomplished, is the cause as well as the subject of the resulting power.

### *Of the Galvanoscopic Frog.*

337. It must follow, from the facts already alluded to, that the limb of a frog must combine all that is essential to a galvanic triad; and, agreeably to the observations of Matteucci,\* sections of the muscles either of warm or cold-blooded animals are competent to give discharges analogous to those of a very feeble galvanic triad. The

*Calorimotor of Two Pairs, or Triads.*

Fig. 8.



The apparatus represented by the preceding figure is a calorimotor quite analogous in construction to that above described, but which differs from it in being only one-fourth of the size, and in consisting of two pairs instead of four. The plates are nine inches by seven. There are four of zinc, and six of copper.

In the form of sheets arranged as two pairs alternating, Faraday, in some of his researches, employed a calorimotor.

Of course, when consisting of more than one triad, the calorimotor ceases to operate under the head of simple circuits. It operates, when constituted of more than one triad, upon the principle of a compound circuit, which will be explained in the next chapter.

\* Annales de Chimie et de Physique, Troisième Serie, Tom. 7, page 435

organs by which electrical fishes are enabled to give shocks to produce ignition, or deviations of the galvanometrical needle, are, no doubt, a series of galvanic triads, in which organic masses, associated in a series voltaically, perform the office of the plates in galvanic triads, forming a compound circuit, of which the description and explanation is the subject of the next chapter.

### *Experimental Illustration.*

338. The electrical excitement arising from the contact of copper and zinc, shown by means of the single leaf electrometer.

339. Effect of the active circuit upon Schweiger's galvanometer and the gold leaf galvanoscope. Also, upon a leech or prepared frog.

340. Disks of zinc, provided for the purpose of producing a galvanic discharge through the tongue, when severally placed over and under it; the projecting limb of each disk being brought into contact.

341. A plate of copper and a plate of zinc, connected by a small wire, being plunged into a vessel containing a dilute acid, the ignition of the wire is produced. The same result obtained, by concentric coils of sheet copper and sheet zinc: also by several plates of copper and zinc, alternated with each other; all the copper plates being associated by one metallic bar, and all the zinc plates by another. These heterogeneous surfaces have, every where, interstices between them, and are connected only by a small wire, which is deflagrated as soon as they are immersed in an acid.



## CHAPTER II.

### OF COMPOUND CIRCUITS, OR VOLTAIC SERIES.

342. Having briefly described the construction and the process of a single galvanic triad, or elementary battery as it is usually called, I will, in the next place, direct at-

tention to the compound or complex circuits, consisting two or more triads. For the illustration of this more complicated form of the galvanic battery, a series of triads will answer every purpose, since, were any number however great, interposed between the terminating triads, each would be in a situation, theoretically and practically perfectly analogous to the triad occupying the mean space in a triple series.



343. Let us suppose three galvanic triads like that represented by Fig. 9 to be situated side by side, no metallic communication existing between the plates of any one triad, while each plate in each communicates, by a metallic conductor, with one of a different metal in one of the triads on either side; also, let the extreme plates communicate by wires, meeting as represented.

344. The plates of neither triad communicating directly, neither can form an *independent* circuit, but still among them may make a discharge through the complex conductor, formed by the uniting wires, and the intervening portions of the exciting liquid. It follows, that if the plates in the exterior receptacles were both of one metal so as to be incapable of producing a galvanic current, the middle triad would act as a simple elementary battery, forming its circuit through a complicated conductor. As in the actual construction, the plates of each triad are similarly excited, the disposition to discharge electricity exists in each. In other words, each copper plate becomes surcharged, each zinc plate deficient, to a commensurate extent.\* Hence, the redundancy engendered in the copper plates, is neutralized by the deficiency engendered in the zinc plates; and no more of the fluid can pass at any point which may be selected, than that which is generated by the two plates, between which the selected point exists. Intensity is all that is gained in the complex circuit. If all the pairs have to use one complicated circuit, they cooperate to effect a current in that circuit.

\* It should be recollected that the zinc, discharging through the liquid to the copper, renders this metal proportionably redundant, and becomes proportionately deficient.

345. During the operation of a single circuit, the discharge from the zinc to the copper, through the liquid, is compensated by that of the copper to the zinc, through the wire, excepting so far as the current is retarded by the obstruction created by the nature or dimensions of the conductor interposed.

346. In the compound circuit, the discharge from the zinc to the copper of each triad, through the liquid, is compensated by the discharge from the copper of one pair to the zinc of the other, and as the deficiency in each zinc plate is exactly equivalent to the surcharge produced in each copper plate, it is evident that the equilibrium must be restored almost as soon as destroyed, where the conducting communication between each pair and that between the extremities is very ample. But after making the communications ample every where else, if there be a deficiency arising either from the size, or the nature of the interposed body, between any two of the triads, the whole of the series will cooperate to effect a discharge through it. So long as this cannot be accomplished, the copper and zinc plate of every triad is brought into an opposite state of polarity, producing a tension, or in other words, an effort to effect a discharge. Hence, the intensity of the effort to overcome the obstruction, is as the number of triads, excepting the loss by retroconduction. This loss necessarily augments in an increasing ratio, so that there is probably a point, at which any numeric extension would injure by promoting retroconduction, more than it would contribute to the intensity.

347. Usually, a galvanic series is considered as composed merely of *pairs*, each consisting of an electro-negative and an electro-positive metal, copper and zinc, for instance. This was the idea of the inventor, who erroneously ascribed the energy of his apparatus to an electro-motive power in the metals, treating the liquid interposed as performing only the humble office of transmitting the electricity from one of the electro-motive surfaces to the other.

348. The first construction of the Voltaic series was that of a pile of such pairs, separated from each other by moistened cloth or pasteboard. Hence, the appellation *Voltaic pile* is often used to signify a series of galvanic triads in any form. Fig. 10 may give an idea of the cele-

Fig. 10.



brated pile of Volta, which has immortalized the name of the inventor, and given rise to results unsurpassed in importance by those of any other invention. The first four, and the last two zinc and copper plates, are distinguished by the letters, C Z. By these means the relative position of all the plates may be understood, as well as those of the disks of cloth represented by intervening dark lines.

349. The following is the account given of his invention by Volta, in a letter to the president of the Royal Philosophical Society of Great Britain:

350. "The principal result is the construction of an apparatus which, as respects the shocks it is capable of giving to the arm, resembles that of a Leyden jar, or of an electrical battery feebly charged, but which shall act incessantly, being self charged after each explosion; which is, in fact, endowed with an inexhaustible charge, or perpetual action or impulsion, upon the electric fluid, but which is peculiar in this power of continuous action; and, moreover, is peculiar in not consisting, like the ordinary batteries, of one or more jars coated by conductors. The apparatus of which I write, is an assemblage of good conductors of different kinds, arranged in a certain manner. Twenty, forty, or sixty, pieces of copper (or better of silver, each applied to a piece of tin (or much better of zinc), and an equal number of strata of water, brine, ley (or other solution which conducts better than water alone), or pieces of card, skin, &c., soaked with any of these liquids; these being interposed between each couple of the different metals alternately, so as to have the three kinds of conductors arranged in the same order throughout. Such is the constitution of the new instrument. This instrument imitates, as I have alleged, the effect of Leyden jars, or batteries, in giving similar shocks, which are, nevertheless, as evinced either by the noise or force of the explosion, the length of the spark, &c., very inferior in intensity to those given by batteries of coated glass, when highly charged. Although equivalent only to a battery of immense surface, very feebly excited, the pile has the preëminent virtue of not requiring to be charged in advance, by an electrical machine, in order to give shocks as often as it may be properly touched.

351. "I propose to call this instrument the artificial electrical organ, as having both in principle and form, as I have constructed it, much greater resemblance to the electrical organ of the torpedo, than any other known electrical apparatus. In truth, it is no less than the latter, composed entirely of conductors."

352. After giving minute instructions for the construction of his pile, the author states, "should it comprise twenty of the metallic pairs, it will not only be competent to cause the leaves of a condensing electrometer to diverge, but will give a charge adequate to a spark, and to create a sensation in the fingers, as often as they may be brought into contact with the extremities simultaneously, resembling that of a torpedo, which has been extremely enfeebled."

353. It is remarkable, that Volta in this communication took not the smallest notice of the rapid decline of power, which ensues in his apparatus, and the fact that it soon becomes comparatively effete. The only recog-

diminution which he makes of this decline is accompanied by the suggestion, that being caused by the evaporation of the moisture, it might be prevented by a resinous covering. But the inadequacy of the escape of moisture to explain the diminution of power, ought to have been sufficiently evident from the striking fact, that this diminution ensues in the *couronne des tasses*. In this apparatus, as well as in the pile, the acid becomes saturated, and the plates coated with reduced copper and suboxide of zinc, although, from the ample supply of water, there can be no injurious desiccation.

### *Of the True Members of a Voltaic Series.*

354. I have endeavoured to make it evident, that the apparatus, which has been called an elementary battery, or galvanic pair, is more properly considered and designated as a galvanic triad; since to form it requires, at least, three agents. Consistently, the metallic pair, belonging to each triad, comprised in a voltaic series, does not consist of the plates which touch each other, but of those which are separated by the exciting liquid, whether held in cells or interposed cloth. Erroneously ascribing the power of his series to an electromotive power, and conceiving the agent intervening between the metallic couple as acting merely as a conductor, Volta constructed his pile, as represented by fig. 10, in which there are two useless plates, one of each metal, at the extremities. The series really commences with the lowermost zinc plate, and ends with the uppermost copper plate, and as the current is from zinc to copper within, and from copper to zinc without, as represented by the arrows, fig. 10, it follows, that when rightly constructed, the copper end is positive, the zinc end negative. The addition, by Volta and his imitators, of two useless plates, as above stated, has led to a general impression, that the true zinc end of a series is positive, and the true copper end, of course, negative, contrary to the real state of the case.

355. I consider the original pile of Volta, and every other modification of the voltaic battery, as consisting of a series of elementary batteries, each alone competent to supply a galvanic current, and to the accumulated powers of which the energy of the whole is due. But such batteries do not severally consist of the two plates of metal which are in contact, or united by a wire or strap, but of two plates, forming a triad with the interposed exciting liquid. But if such a pile consists of such triads, making the base negative, we must begin the pile with zinc, and of course terminate it with copper.

356. Since, when a wire or strap is made to proceed into a liquid, from the copper plate really forming the positive or delivering end of the series, it occupies the place which a zinc plate would occupy in the next additional cell in the *couronne des tasses*, or Babbington's apparatus, were the series extended, Daniell designates the surface of such a wire or strap, as the "zincode." This appears to me objectionable, since it tends to produce a narrow association of a general property with a particular metal. Though it may be truly alleged, that the zincode occupies the place which the generating metal zinc, would occupy; yet, nevertheless, it does not act as a generating metal. It does not, like the preceding zinc plate, contribute to the current.

357. Faraday has proposed to call the poles of the voltaic series, electrodes, from *ēdēs*, a way, and *electron*; the sectional polar areas thus designated, being the passages through which the electricity is assumed to flow into or out of the series when the circuit is in operation. Supposing the wires of the series, those of fig 9, for instance, to be introduced into water,

so as to take a portion of this liquid into the circuit, that end of the row of atoms of water which touches the wire proceeding from the copper plate in the liquid, is called by the same author the *anode*, while the other end of the row in contact with the wire, proceeding from the first zinc plate in the series, is called the *cathode*.

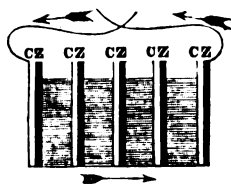
358. In order to understand the etymology of these words, it may be expedient to refer to the fact already mentioned, that the magnetic axis tends always to take a position at right angles to an electrical current, to the influence of which it is sufficiently exposed. The direction of the compass needle is ascribed to such a current, caused by the progression of the solar heat from east to west, consequent to the diurnal rotation of the earth. In the case of any portion of the crust of the earth subjected to the thermoelectric currents, originating as suggested, the fluid will enter from the east, or where the sun rises, hence anode, from *ανα*, upwards, and *οδος*, a way. Again, the fluid passing out westward, we have cathode, from *κατα*, downwards, and *οδος*. It follows, that any mass of liquid or other body made to complete the circuit, by having each of its extremities in contact with the ends of the wires forming the electrodes of a galvanic battery, the part in contact with the positive pole will be the anode, while the part in contact with the negative pole will be the cathode.

359. I shall, however, continue to designate the poles as they have been heretofore named, using also Faraday's new appellation (electrode) for either. Noad has judiciously, as I think, proposed that the positive pole be designated as the anelectrode, the negative pole as the cathelectrode.

360. The process of decomposition, as effected by the voltaic current, is by Faraday, designated electrolysis, from *electron*, and *λυο*, to untie or free from bondage. A substance, susceptible of this process, is designated as an electrolyte, and is said, when subjected to it, to be electrolysed. Its elementary constituents are called *ions*, from *ιο*, to go. That which is evolved at the anode, anelectrode or positive pole, is called an anion, while the other, which is evolved from the cathode, cathelectrode or negative pole, is called a cation or cathion.

361. In stating the dimensions of a pile, it is most convenient to mention the size of the pairs, and the whole number associated in the series. As there must be two plates for every triad, this mode of estimation causes no error in fact, however it may tend, when unnoticed, to be productive of a hypothetical misconception. In the voltaic pile, fig. 10, the electro-negative and electro-positive metals, copper and zinc for instance, are in contact. Hence, there is no necessity for a conjunctive wire or strap to enable the copper of one triad to discharge to the zinc of the other, as in figures 4 and 9. I hold this language, under the impression that the elementary batteries, or triads, forming the series, consist each of *a copper and zinc plate which do not touch or communicate otherwise than through the liquid*, as of those which are in contact as in the pile, or connected by a wire as in the couronne des tasses, figure 9.

Fig. 11.



362. Soon after the pile and the couronne des tasses were invented by Volta, another form of the voltaic series was contrived by Cruikshank, one of the most distinguished chemists of his time. Of this, figure 11 is a representation: usually it is designated as the Cruikshank trough. The parts of this apparatus consist of a zinc and copper plate of similar dimensions, united so as to bring their corresponding surfaces in contact throughout. Each



pair forms one partition, consisting, on one side, of copper, on the other, of zinc. The partitions thus formed being inserted in an horizontal trough, have between them interstitial cavities for holding the acids, and which consequently perform the office of the cloth in the voltaic pile. Of course, the metals must be in the same alternate order as in the pile. The right side of the partitions being all of one kind of metal, those on the left must all be of the other: so that looking down at the trough obliquely from one end, we see none but copper surfaces; when looking from the other end, we see none but zinc. It is better, however, to have an extra copper plate at each end, to which to solder the rods or wires employed to communicate the galvanic current, or to act as the electrodes. These plates should be attached severally to the pieces of board forming the ends of the trough. This successive alternation of copper and zinc, or any other masses having a similar efficacy, whether organic or inorganic, I shall designate as *voltaic order*, being that which is essential to any modification of what we call the voltaic series, whether natural or artificial.

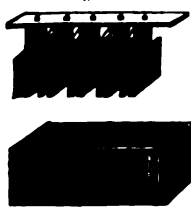
363. The analogy between the Cruikshank trough and the pile must be evident, since, if we place the trough upright, and after filling the cells between the pairs with moistened cloth, remove the wood, we shall have the voltaic pile in the form of a rectangular prism.

364. The trough of Cruikshank has great advantages over the pile, or the *couronne des tasses*. As the energy of the current diminishes with the activity of the acid, and this is lessened in abundance and strength by reaction with the zinc, the quantity which can be held by the cloth is soon exhausted; and although, in the *couronne des tasses*, the supply of acid was as much too great, as in the pile it was too small, the plates could not be kept parallel, nor sufficiently near without liability to touch each other. In the trough there was an abundance of acid, and the plates, however approximated, were secure from contact: moreover, the Cruikshank trough, as since modified by me, in order to comprise an equivalent degree of efficacy, need not occupy a tenth part of the space required by the *couronne des tasses*. Again, the contact is immediate and more effectual between the zinc of one pair, and the copper of another.

365. The direction of the current in the trough is indicated by the arrows in the figure. It will be observed, to obey the general law of the circulation, as already mentioned, it proceeds from zinc to copper within the liquid, and from copper to zinc through the wire.

366. The analogy between Babington's apparatus, fig. 12, and the *couronne des tasses*, is as great as that which has been shown to exist between the trough of Cruikshank and the pile of Volta; the superiority of the apparatus of Babington over the *couronne des tasses*, being equally striking.

Fig 12.



367. In Babington's apparatus, a trough of porcelain is so constructed, as to have in it partitions of the same material, dividing the interior into ten or more cells of a rectangular shape. With a view to economy both of the sheet metal employed and space, the plates are made also of a corresponding rectangular shape. We have seen that in the pile, and in the Cruikshank trough, the triads communicate by direct contact. In the apparatus of Babington, a communication between them is established by straps of copper, which serve also to attach severally to one beam each couple appertaining to one trough, so that they may be simultaneously introduced into or

removed from the cells. By these means to cause the reaction between the plates approximate with greater convenience. It is under consideration formed with porcelain the tumblers of the *couronne des tasses* wires, and square plates for disks. This is virtually a *couronne des tasses*, very convenient, and efficacy.

368. The great apparatus of Davy's troughs of ten pairs each, upon Babinet's two thousand triads.

369. Subsequently, agreeably to the apparatus, otherwise constructed like the rounded by copper, contact being prevented of the zinc was conceived to be increased.

370. The celebrated apparatus of Clouston's plan; it consisted of twenty pairs of copper coupled by a metallic strap, and each pair was situated between the two tared six feet by two feet eight inches.

371. Subsequently, adopting the same respects surrounding the zinc by copper, dred pairs, in which the vertical edge of copper, instead of the upper and lower importance in diminishing the necessity thus constructed were separated by being not insulated any further than as copper, on which voltaic action depends.

the arrangement of my apparatus, was to throw the whole of the acid on or off of

\* The opinions of Faraday respecting the be found in the following abstract republic Sciences. They are preceded by the following guished editor of that Journal. See Vol. XI.

"An account was given in this Journal (Volume 3) by Dr. Hare, of his galvanic deflagration to their size in producing intense ignition. Dr. Hare were, with some additions, repeated the allegations of the inventor were also Hare's memoirs and ours, with engravings, in the *Encyclopædia* and *Philosophical Magazine*, London, and were imitated in Europe, the old and in rural use. It is satisfactory to find, from the Faraday, that the course of his investigation deflagration of our countryman as the most equitable those passages of Mr. Faraday's paper tend to justify our statement.

"The advantages of this form of trough are exceedingly compact, for one hundred pairs more than three feet in length. 2d. By Dr. upon copper pivots which rest upon copper batteries; and these I have found it very convenient, fastened in the front of the stand of the give the great advantage of arranging an apparatus *before* the latter is put into action. 3d. use in an instant, a single jug of dilute acid hundred pairs of four inch plates. 4th. On 1

372. It was the power of simultaneously lowering or lifting all the plates attached to a beam, that caused a preference to be given to the apparatus of Babington's construction, over that of Cruikshank. Yet as it was found expedient, by Davy and others, to attach no more than ten couples to a beam, the object of an instantaneous and simultaneous immersion of the whole series in the liquid, or that of its extrication therefrom, could not be effected conveniently upon the Babington plan.

373. I succeeded in this object by various constructions, which I have designated generally as galvanic deflagrators. It may be inquired, in what respect do series thus constructed so much differ from others as to deserve a peculiar name? The reply is, that in voltaic series, as employed by its inventor, and as used by all subsequent operators, the plates were necessarily subjected to the exciting reagent in the first instance, the circuit being completed by a communication, subsequently made, between the electrodes. In that construction, to which I give the generic term deflagrator, the circuit may be completed by the simultaneous exposure of the whole series of plates to the exciting reagent, either simultaneously with, or subsequently to, the completion of the rest of the circuit.

374. Turner alleges, that an advantageous variation of this contrivance was made by Mr. Hart, of Glasgow, by which the copper was formed into a hollow paralleliped. This construction was resorted to by me as early as the year 1822, but not finding it as convenient for filling and emptying

ter of a revolution, it becomes active, and the great advantage is obtained of procuring for the experiment the effect of the *first contact* of the zinc and acid, which is twice or sometimes even thrice that which the battery can produce a minute or two after. 6th. When the experiment is completed, the acid can be at once poured from between the plates, so that the battery is never left to waste during an unconnected state of its extremities; the acid is not unnecessarily exhausted; the zinc is not uselessly consumed; and, besides avoiding these evils, the charge is mixed and rendered uniform, which produces a great and good result; and, upon proceeding to a second experiment, the important effect of *first contact* is again obtained. 6th. The saving of zinc is very great. It is not merely that, whilst in action, the zinc performs more voltaic duty, but *all* the destruction which takes place with the ordinary forms of battery between the experiments is prevented. This saving is of such extent, that I estimate the zinc in the new form of battery to be thrice as effective as that in the ordinary form. 7th. The importance of this saving of metal is not merely that the value of the zinc is saved, but that the battery is much lighter and more manageable; and also that the surfaces of the zinc and copper plates may be brought much nearer to each other when the battery is constructed, and remain so until it is worn out: the latter is a very important advantage. 8th. Again, as, in consequence of the saving, thinner plates will perform the duty of thick ones, rolled zinc may be used; and I have found rolled zinc superior to cast zinc in action; a superiority which I incline to attribute to its greater purity. 9th. Another advantage is obtained in the economy of the acid used, which is proportionate to the diminution of the zinc dissolved. 10th. The acid also is more easily exhausted, and is in such small quantity that there is never any occasion to return an old charge into use. Such old acid, whilst out of use, often dissolves portions of copper from the black flocculi usually mingled with it, which are derived from the zinc: now any portion of copper in solution in the charge does great harm, because, by the *local* action of the acid and zinc, it tends to precipitate upon the latter, and diminish its voltaic efficacy. 11th. By using a due mixture of nitric and sulphuric acid for the charge, no gas is evolved from the troughs; so that a battery of several hundred pairs of plates may, without inconvenience, be close to the experimenter. 12th. If, during a series of experiments, the acid becomes exhausted, it can be withdrawn, and replaced by other acid with the utmost facility; and after the experiments are concluded, the great advantage of easily washing the plates is at command. And it appears to me, that in place of making, under different circumstances, mutual sacrifices of comfort, power, and economy, to obtain a desired end, all are at once obtained by Dr. Hare's form of trough."

as other constructions, the parallelopeds were laid aside, and are still in my laboratory.

375. I shall introduce into an appendix, engravings and descriptions of several forms of voltaic series to which I successively resorted. The construction to which I have finally given preference, is that of a Cruikshank trough, so modified as to increase its power, to enable it to act as a deflagrator, and render it possible to scrape the plates.\*

\* *Engraving and Description of a Deflagrator of Two Hundred Pairs of Fourteen Inches by Seven and a half, being one of the Members of a Pair of Troughs, both of the same size, and which may be used collaterally or consecutively.*

Fig. 13.

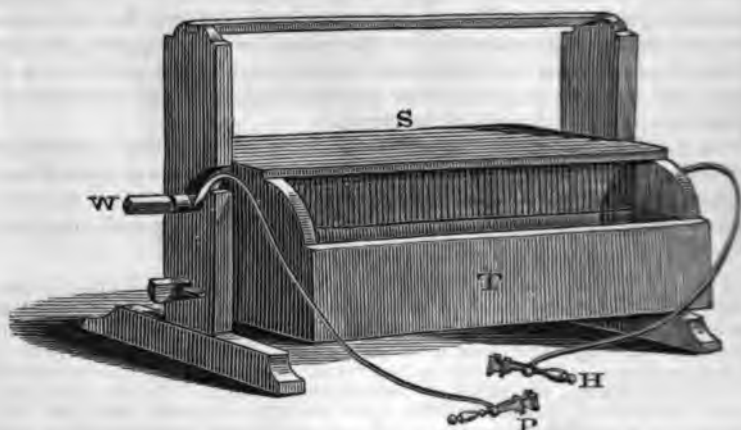


Fig. 13 represents a deflagrator. It consists of a wooden trough upon the Cruikshank plan, joined lengthwise, edge to edge, to another trough, so that when the sides of the one are vertical, those of the other must be horizontal. The advantage of this arrangement is, that by a partial revolution of both the troughs, thus united, upon pivots which support them at the ends, any fluid which may be in one trough must flow into the other; and, reversing the movement, must flow back again. The galvanic series being placed in one of the troughs, the acid in the other, by a movement such as described, the plates may all be instantaneously subjected to the acid, or relieved from it. The pivots are made of iron, coated with brass or copper, and less liable to oxidization. A metallic communication is made between the coating of the pivots, and the galvanic series within. In order to produce a connexion between one trough of this description and another, it is only necessary to allow a pivot of one trough to revolve on one end, and a pivot of the other trough to revolve upon the other end of a strap of sheet copper. To connect with the termination of the series, the leaden rods, to which are soldered the vices, or spring forceps, for holding the substances to be exposed to the deflagrating power, one end of each of the lead rods is soldered to a piece of sheet copper. The pieces of copper thus soldered to the lead rods, are then to be placed under the pivots, which are, of course, to be connected with the terminations of the series. The last mentioned connexion is conveniently made by means of straps of copper, severally soldered to the pivots, and the poles of the series, and screwed together by a hand-vice. Each pair consists of a copper and a zinc plate, soldered together at the upper edge, where the copper is made to embrace the edge of the zinc. The three remaining edges are made to enter a groove in the wood. For each inch in the length of the trough there are three pairs. In the series represented by fig. 13, there are one hundred pairs of nearly fourteen by seven and a half inches.

The pair of troughs, forming, when associated, a single deflagrator, of which one is represented by fig. 13, may be employed either by connecting them at their base

*Of the different Modes in which the Power of a Galvanic Battery may be augmented.*

376. Obviously there were two modes in which the power of a galvanic battery could be augmented; one was that of increasing the size of the plates of each pair, the other that of increasing the number associated as a series.

377. It has been mentioned, that under the name of calorimotor, the elementary battery or galvanic triad (312) was first made of gigantic size in this country (324). By Vollaſton it had been tried in the minute form of a silver thimble, of which the cavity was occupied by a minute cylinder of zinc surrounded by a potent exciting liquid. In the calorimotor the number was reduced to unity, while the size was enormously increased, the liquid being highly energetic. In Davy's pile of two thousand pairs, the number was comparatively very large, the energy of the liquid as great as could be used with advantage. By Daniell, the number has been carried to three thousand five hundred and twenty, excited by a liquid of no higher energy than river water.

378. In the voltaic series thus employed by Crosſe and Daniell, we ſee that the number of the triads is exceedingly large, while the activity of the liquid is brought down

to homogeneous or heterogeneous extremities. When connected at their homogeneous ends, they act *collaterally* as a ſeries of one hundred pairs of fifteen by fourteen; when connected at their heterogeneous extremities, they act *conſecutively* as a ſeries of two hundred pairs, each fourteen by ſeven and a half. Of courſe, agreeably to the firſt mentioned arrangement, we double the quantity, the intensity being unaltered: according to the arrangement laſt mentioned, the intensity is doubled without an increaſe of the quantity.

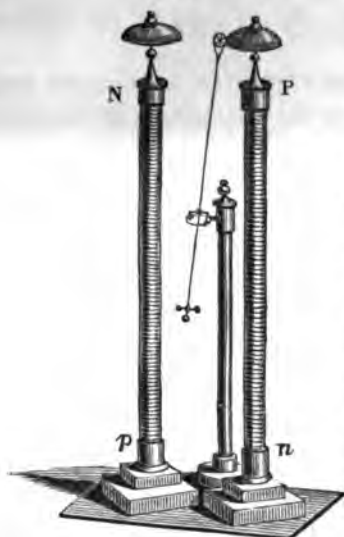
It may be proper to mention, that theſe Cruikſhank deſlagrators are ſo conſtructed, as that the plates may be ſcraped after each operation. Every fifth plate is cemented, ſo as to form a water-tight partition. As the plates are purpoſely ſo cut, as to leſſen in width from the upper to the lower edge, thoſe which are not cemented may be eaſily withdrawn in order to be ſcraped. But the withdrawal of every fourth removable plate, leaves vacant ſpaces ſufficiently large for the introduction of a tool uſeful for ſcraping thoſe which are not removable.

A battery of this conſtruction was made, under my direction, for the Lowell Inſtitute, conſiſting of four troughs, each containing one hundred plates ſix and a half inches ſquare. A piece of wooden plank, three inches wide, thirteen inches long, and two inches in thickneſs, is ſo bored by a centre-bit as to have eight cylindrical cavities, all theſe being ſupplied with mercury. By means of ropes of copper wire, the various portions of mercury are made to communicate each with one of the eight poles of the four troughs. Arches of ſtout copper wire are provided of different lengths, ſo that, by variously connecting the mercury in the holes, the whole may be made to coöperate as one ſeries of four hundred pairs each of forty-two inches, or one ſeries of two hundred pairs of eighty-four inches, or one ſeries of one hundred pairs of one hundred and ſixty-eight inches ſurface.

to a minimum, even below that of the saliva in the experiment with the tongue (306), or the sanguineous slime of the frog in the experiment of Galvani (309). But in the column of De Luc no liquid reagent is employed, since it cannot be pretended that the hygrometric moisture of the paper, entering into its construction, exists in the liquid form. This series, as originally contrived, consisted of disks of silvered paper alternated with disks of zinc as thin as possible, and each of about five-eighths of an inch in diameter. An analogous series, devised by Zamboni, consists of disks of the same size, coated on one side with leaf tin, on the other with a paste of black oxide of manganese and sulphate of zinc. According to Daniell, a series of this last mentioned construction has been made, comprising 20,000 pairs, respecting the powers of which an account will be given in due course.

*Engraving and Description of the Electric Columnar Apparatus of De Luc, as modified by Zamboni.*

Fig. 14.



379. Of an apparatus of the above mentioned construction, the adjoining figure is a representation. It consists of two columns, which communicate by a plate of zinc. The letters P p show the ends forming the positive poles, while N n indicate those forming the negative poles. The anode of one, and the cathode of the other, communicating through the zinc plate, it must be evident that the columns are so arranged as to act consecutively. (See note, page 22, 2d paragraph.)

380. No doubt the electric columns owe their efficiency to that electromotive process, which, in other apparatus, causes an electric accumulation at the electrodes; but the phenomena are almost exactly those of electricity created by friction.

381. When the apparatus represented by the engraving was recently constructed, it produced sparks at every

contact of the bells with the pendulum. It communicated a charge to a small coated glass cylinder, sufficient, in passing through the thumb and finger, to give a shock extending to the wrist. After it had been constructed for more than ten years, when warmed it would cause a gold leaf to vibrate between balls severally communicating with the electrodes. The

Two columns comprise about 4500 disks of tinned paper, coated, on the otherwise naked side, with manganese and sulphate of zinc.\*

*On the Construction of De Luc's Columns, as modified by Zamboni; and on a Modification of the Single Leaf Electrometer contrived by the Author, by which the ultimate efficiency of a large electric series may be ascertained, by testing a small portion of the members of which it is to be constituted.*

About fifteen years ago, the construction of De Luc's electric columns, as modified by Zamboni, was undertaken by Isaiah Lukens, one of our most skilful and ingenious mechanicians.

The materials employed were paper covered with leaf tin (erroneously called silvered paper), peroxide of manganese, and crystallized sulphate of zinc.

The peroxide was finely pulverized and mixed with a concentrated solution of the sulphate. The mixture thus formed was, by means of a brush, applied like a pigment to the surfaces of the paper not coated by the tin. The sheets were afterwards spread out on the floor of an apartment, and left during the night to dry. By these means, unnecessary exposure to light was avoided, which Mr. Lukens conceives to be injurious, especially as received directly from the sun. Next day the sheets were cut into disks of about five-eighths inch diameter, by means of a hollow punch. The disks were then piled, with the heterogeneous surfaces alternating, as in other voltaic series, and were introduced into, and compressed within, glass tubes, accoutred as usual with pedestals, caps, and bells. Notwithstanding his skill and experience, Mr. Lukens latterly complained of occasional want of success, arising, as he supposed, from the defective quality of the manganese. In various instances, his columns, after being constructed with the utmost care, proved inert.

The manipulation, likewise, according to his plan of operating, appeared to me to be troublesome and precarious. He was accustomed to place a row of the disks, as large as could be conveniently handled, in a trough of sheet metal, and then transfer the pile thus formed to the glass tubes. This operation, to be successful, required dexterity.

In February, 1833, wishing to replenish the tubes of a pair of electric columns which had become effete, I contrived to avoid the risk of expending the labour and attention requisite to finish a series, while uncertain as to its eventual efficiency. I

Fig. 15.

A



### Of Groves' Gas Battery.

382. "In the L. and E. Phil. Mag. for December, 1842, a most extraordinary and perfectly novel voltaic battery is described by the inventor, Mr.

contrived, likewise, by a very simple expedient, to facilitate the process of piling the disks.

The first mentioned desideratum was obtained by means of a single leaf of gold, suspended in a glass vessel (represented by the subjoined figure), between two knobs at the ends severally of two brass rods, B B, proceeding through opposite sides of the vessel towards each other, so as to be capable, if requisite, of meeting in the centre. By means of screws, the knobs on these rods were susceptible of being adjusted to any distance from the gold leaf suspended between them. Externally the rods are so made and placed, as to be easily connected with wires. In the gold leaf thus situated, vibrations may be produced by a series of disks, comprising not more than one-twentieth of the number necessary to cause such a pendulum as commonly pertains to the electric column, to oscillate. In the case in point, I found that the disks produced by one sheet of paper, were sufficient to make the leaf vibrate actively between the knobs. The mode in which this effect was produced, may be understood from the following figure, which represents the disks, as compressed, in due order, within a glass tube, by spirals of wire.

Each of the wires of which these spirals were formed at the ends enclosed in the tube, being unaltered throughout the remaining portions of their length, were passed through corks closing the orifices of the tube. The series thus prepared, is to be

Fig. 16.



placed in the situation of the electric column, appended to the instrument agreeable to fig. 15, being in like manner suspended from the rods outside of the vessel, by means of the projecting wires already mentioned. Thus situated, if there be any adequate degree of electromotive power in the series under trial, and the atmosphere sufficiently dry, the excitement of the poles will be communicated to the knobs, and be indicated by the consequent vibrations of the gold leaf suspended between them.

When a larger series is used, such as that represented at D D, fig. 15, the vibrations will be discontinued, only in consequence of the adherence of the leaf to one or the other of the knobs. This adherence usually ceases, on touching with a finger the little brass ball at the vertex of the instrument, to which the forceps holding the leaf is affixed. The finger being removed, vibratory pulsations will recommence, to be sooner or later arrested in the same manner as at first.

When the knobs, B B, were properly connected with the poles of a voltaic battery, of seven hundred pairs, excited merely by pure water, the pulsations of the leaf were quick and incessant. These pulsations may indicate the electric intensity, but do not furnish any criterion of the divellent igniting, or electro-magnetic powers of a voltaic series.

It may readily be perceived, that the electrometer, constructed as herein described, constitutes an electrical discriminator, which may enable us to discover the electromotive powers of various substances arranged as disks in a series, or as coatings to disks. I have already ascertained that aurum musivum, spread on the naked surface of the tinned paper, produces an electromotive series.

The piling of the disks was facilitated by using a punch excavated so as to leave a point in the centre, by which the centre of each disk was punctured. By means of the puncture thus made, it was easy, even for an unskilful operator, to string them concentrically upon a silk thread, and to transfer them to the tubes without derangement.

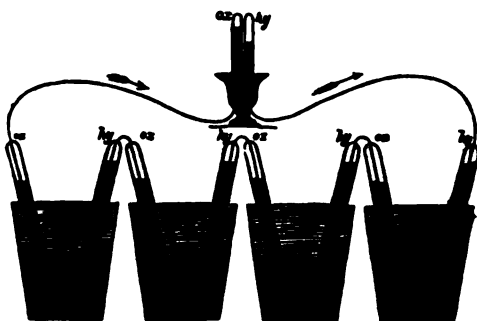
The manganese which I employed with success, in the replenishment of the electric columns alluded to above, consisted mainly of needle-shaped radiated crystals, aggregated into lumps. Mr. Lukens alleges that the crystallized manganese is always, agreeably to his experience, proved the best for the construction of electric columns.

The electrometer, with an electric column attached to it, as above represented,



rove. It consists of a series of fifty pairs of platinized platinum plates, each about a quarter of an inch wide, enclosed in tubes partially filled, al-

Fig. 17.



ternately with oxygen and hydrogen gases, as shown in fig. 17. The tubes being charged with dilute sulphuric acid, sp. gr. 1.2, the following effects were produced:—

“1st. A shock was given which could be felt by five persons joining hands, and which, when taken by a single person, was painful.

“2d. The needle of a galvanometer was whirled round, and stood at about  $60^{\circ}$ ; with one person interposed in the circuit it stood at  $40^{\circ}$ , and was slightly deflected when two were interposed.

“3d. A brilliant spark, visible in broad daylight, was given between charcoal points.

“4th. Iodide of potassium, hydrochloric acid, and water acidulated with sulphuric acid, were severally decomposed: the gaseous elements from the decomposed water were extricated in sufficient quantity to be collected and detonated. They were evolved, as chemical theory and experience would indicate, the hydrogen at the anode, the oxygen at the cathode. It was

may serve to show the nature, as well as the extent of electric excitement; since, when an electrified mass is made to communicate with the brass ball, A, from which the leaf is suspended, the latter ought to be attracted by that knob, which receives from the series an opposite excitement. Hence, the excitement of the electrified body being known, that of the poles may be detected: or the latter being known, the excitement of the body may be discovered. This application of the electric series is not, however, a new idea. I saw many years ago a notice of an electrometer, associated with an electric column, in such manner as to be used as an electrical discriminator.

The great difficulty in resorting to this means of discrimination is, that an electrified body may, by induction, produce in a conductor alternately, opposite states of electrical excitement. As it approaches the conductor, it may cause it to receive, or give out electricity; of course, when retracted, the conductor will have the opposite excitement to that consequent to approximation. Supposing the brass ball of the electrometer in question, to be affected in the mode just described, the leaf suspended from it must be successively attracted by each pole. Besides, the excitement may be so strong, as to render that of the series nugatory; as in the case of a powerful magnet, which will attract either pole of a feeble one.

The direction of the first pulsation of the leaf is the best criterion; but reliance should not be accorded to one experiment, especially when so easily repeated. I find that a gilt pith ball, if suspended in place of the leaf, will vibrate for a time. It is, however, like the leaf, liable to have its movements arrested by an adherence to one or other of the knobs.

found, that to decompose water, twenty-six pairs were requisite, but four pairs would decompose iodide of potassium.

"5th. A gold leaf electroscope was perceptibly affected.

383. "When the tubes were charged with atmospheric air, no effect was produced, nor was any current determined when the gases employed were carbonic acid and nitrogen, or oxygen and nitrogen.

384. "The original experiment was not made with sufficient exactness to show with accuracy the proportional diminution of gas in each tube, though it was plain that the hydrogen diminished much more rapidly than the oxygen."

385. The electrodes are represented as terminating in tubes for each of the gaseous elements of water, evolved by the electrolytic power of the same elements, under the electro-polarizing influence of platinum.

*Of the Electrolytic Process by which the Galvano-Electric Current is propagated within Liquid Reagents.*

386. Before giving an account of these forms of the galvanic series, in which more than one chemical reagent is employed, it may be expedient to enter more fully into the rationale of that part of the galvanic process, in which the electric fluid is supposed to be transferred from the zinc to the copper, through the exciting liquid.

387. Faraday assumes, that the fundamental cause of the hydro-electric current, or that produced by the reaction of metals with liquids, is the chemical affinity between one of the metals employed and an ingredient of some electrolyte contained in the liquid, and that the combination of an atom of the metal with an ingredient atom, taken from the liquid electrolyte, causes an equivalent discharge of electricity from the atom so taken.

388. Thus, when zinc combines with the oxygen of water, performing the part of an electrolyte, a discharge of electricity from the atom of hydrogen is a necessary consequence. Hence, in some cases, as, for instance, that of pure zinc exposed to diluted sulphuric acid, unless the requisite charge be facilitated by contact with a metal not capable of combining with oxygen, no combination ensues. But, under the same circumstances, while the oxygen of the liquid is attracted by zinc, the liquid being in contact with a plate not liable to be oxidized by it, the discharge of electricity is facilitated, as soon as a conducting communication is established between the metals. He supposes a series of decompositions and recompositions to place within a row of the particles of water lying between the zinc and copper surfaces, so that the atom of oxygen next the zinc surface, uniting with an atom of this metal, discharges its electricity to the next atom of hydrogen, which unites with the oxygen of the next atom of water. But in doing this, it causes the transfer of its electricity to the third atom of hydrogen. This process being repeated, an atom of hydrogen surcharged with electricity, is evolved against the copper surface. Hence the surcharge acquired by the copper goes through the connecting wire, to restore the electric tension within the zinc which the chemical reaction tends to diminish, as above stated.\*

\* If we suppose, in a dance, a number of girls and boys standing in a row, in couples, alternately arm in arm, alternately separate, and that a girl is suddenly taken from one end of the row, and a boy from the other end, evidently of each sex there would be an individual isolated. But if, simultaneously, each girl relinquishes her hold on the partner of which she had the arm previously, takes that of the next on the other side, there will be no individual of either sex in a solitary state.

389. The idea that the exchange of hydrogen at one electrode, and oxygen at the other, is the effect of a series of decompositions and recompositions, as above stated, was originally suggested by Grothus, as accounting for the fact, that the extrication of hydrogen and oxygen from electrolysed water does not take place at the same rate. It had been objected that it was inconceivable that the elements of water, arising from the decomposition of a succession of atoms of this liquid, could be severally evolved at the distance of some inches from each other.

390. In the last edition of my *Treatise on Galvanism*, after having cited the electrolytic theory of Faraday, (386, 387,) I subjoined the following remarks:—

391. Whatever may be the source of the imponderable matter which circulates in voltaic series, I infer, that its confinement within the circuit, and its endowment with an ability to pass over an interval, or to penetrate through imperfect conductors, must be due to an influence of the masses concerned, which has not as yet been satisfactorily explained.

392. Probably upon an analogous ability to produce or annul, to promote or retard, chemical reaction, the efficacy of animal and vegetable organization is founded, being obviously dependent on an arrangement of masses. The voltaic series of a gymnotus is evidently an animal organ, and its analogy with the voltaic series, produced by human ingenuity, induces me to consider the latter in the same class of agents as the organs by which life is supported.

393. The opinions thus expressed by me have, I think, found much to justify them in the facts established by means of Groves' gas battery. In that apparatus, a portion of hydrogen performs the part of zinc, while oxygen performs the part of copper (314). These gases exercise chemical affinity neither with water nor with platinum. An electro-polarizing reaction with the platinum is evidently the only imaginable cause for the union of an atom of gaseous hydrogen with the oxygen of water, at one of the terminating surfaces of that liquid, while, analogously, an atom of gaseous oxygen combines with hydrogen at the other aqueous surface.

394. It appears to me, that precisely the same change must ensue in the electro-polarity of the gaseous atoms during this electrolytic process, as when a mixture of the gases employed, is made to combine by the presence of platinum sponge.

395. But whatever may be the rationale, the phenomena of this gas battery, as well as those previously used, all tend to confirm the fact, that what is called the electric current, in its passage in a galvanic triad from the electropositive surface to the electronegative surface through the liquid, is inseparably associated with a series of decompositions and recompositions.

396. This electrolytic exchange of partners, in rows of atoms which, within the battery, appear to be concerned in the generation of the current, seems, externally, to be one of its effects; so that the evolution of the elements of an electrolyte, severally at the cathode and the anode (358), are ascribed to a series of decompositions and recompositions, like those which accompany the generation of the current.

397. The impression seems to exist among many electricians, judging from their language, that the elements actually travel from one electrode to the other. The choice of the word *ion*, from *io*, to go, (360) is in this respect disadvantageous. In point of fact there can be no such locomotion. Simultaneously with the liberation of an atom of each ingredient at the poles, the residual ions in the electrolytic row, rearrange themselves so as

still to form atoms of the electrolyte. Of course, a greater or less number of the electrolytic atoms will be simultaneously decomposed, out of as many rows existing in due contact with the electrodes; but it cannot be reasonably supposed, that there is not a change of relative position too incessant to permit the electrolytic process to take place twice through precisely the same row of atoms. Probably the loss of an atom can never arise from the interposition of precisely the same residual atoms which have existed once together in a row long enough to lose one atom from among them. As reasonably might a sportsman expect to find in a numerous flock of birds while wheeling about him, the same individuals twice in a line with his rested fowling piece.

398. Between the galvanic batteries above described, in which only one liquid is employed, and those constructed with the aid of two liquid chemical reagents or electrolytes, as in the case of the series of Daniell or Grove, there is this striking difference, that, in the requisite series of decompositions and recompositions, the part performed by hydrogen as the electropositive element on one side of an interposed diaphragm, is on the other performed by copper, nitric oxide, or some other radical more ready than hydrogen to separate from oxygen. The porous diaphragm soaked with sulphate of copper or nitric acid, presents throughout the whole of its area an oxidizing surface which coöperates with the opposite influence of the de-oxidizing zinc to effect the disunion of the elements of water. Hence while the electrolytic exchange is solicited on one side, by the attraction of zinc for oxygen, it is solicited on the other side by the attraction between hydrogen and the oxygen of the other electrolyte with which the pores of the diaphragm are imbued. In nitric acid, nitric oxide, acting as a compound radical, performs the part of the simple radical copper, in the oxide of this metal held in the sulphate. The liberation of one atom of nitric oxide, at the surface of the platina, causes three atoms of oxygen to be yielded to the hydrogen of water at the membrane, more readily than an atom of copper, analogously liberated, causes one atom of oxygen to be yielded. This I conceive to be the main cause of the superior efficacy of Grove's nitric acid sustaining battery, of which a description is given in the following pages. To the advantage thus gained is to be added that of the protection of the metallic surfaces from injurious deposition (315).

### *Of Constant or Sustaining Batteries.*

399. In the year 1835, Prof. Daniell, of King's College, London, made an interesting and important innovation in the construction of galvanic batteries, by the interposition of an animal membrane, the gullet of an ox for instance, between the heterogeneous metallic surfaces. A battery of this kind in my possession, consists of a cylinder of copper, about six inches in height and four inches in diameter. Within an inch and a half of the brim, a diaphragm of copper is inserted. This diaphragm is perforated like a colander, and has, at the centre, a hole of about an inch and a half in diameter. It is through this hole that the gullet is made to descend to the bottom of

the vessel, where it communicates with a glass tube, which is so bent at right angles twice, and so extended as to rise by the side of the cylinder and terminate in a recurved orifice on a level with the brim. A solid cylinder of amalgamated zinc, of half an inch in diameter, is made to occupy the cavity of the gullet.

400. It has already been mentioned, that in this construction, the copper is not liable to be tarnished nor the zinc to be coated by a deposition,\* and thus to be rendered incapable of their appropriate reaction with the interposed liquid. The membrane will not allow a solution of either metal to permeate it, although it permits the transmission of the electro-chemical decomposition and recomposition, by which the voltaic current is sustained. The space between the gullet and the cupreous surface of the enclosing cylinder, is occupied by a saturated solution of sulphate of copper, the cavity within the gullet by diluted sulphuric acid, or some saline solution not liable to be decomposed, *per se*, by zinc. Upon the diaphragm, crystals of sulphate of copper are deposited, for the purpose of preventing any decline in the strength of the solution of that salt. As the diluted acid employed becomes saturated with zinc, it is displaced by a fresh portion which causes that first mentioned to be expelled at the orifice of the glass tube. Of course, the chemical reaction may be kept up as long as the zinc lasts. Latterly, in the construction of Daniell's battery, the glass tube has been omitted, as the advantage arising from its employment, has not been found to compensate for the additional liability to derangement.

401. I saw at the laboratory of Prof. Daniell, an association of his sustaining batteries, of which the power to ignite wire was surprising.

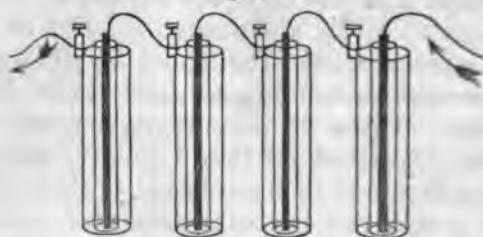
402. According to Brande, with a constant battery of twenty cells arranged in a single series, twelve cubic inches of mixed hydrogen and oxygen may be collected in every five minutes of action; and, when they are connected in pairs and afterwards in a series of ten, the quantity amounts to seventeen cubic inches. Eight inches of platinum wire, one two-hundredths of an inch in diameter, may be kept permanently hot by the same arrangement, and the spark

\* The deposition thus formed consists of a mixture of copper and suboxide of zinc (315, and note).

taken between charcoal points is very brilliant. To the original form of Daniell's battery above described, there is however, a great objection, founded on the employment of an animal membrane, which is of course liable to be injured or spoiled. Porous vessels of unglazed earthenware have been, however, substituted for animal membrane with great increase of convenience, and they are now employed both in this and other forms of voltaic apparatus. Leather has also been successfully substituted for an membrane.

*Engraving and Description of a Voltaic Series of Constant Batteries.*

Fig. 18.



403. The preceding figure will convey a sufficient conception of a sustaining battery, in which cylinders of porous porcelain are substituted for the ox gullet employed agreeably to the original construction of Daniell's apparatus.

404. The external lines represent sections of round copper jars, the dark central lines represent the amalgamated zinc rods, situated in the common axis of the copper jars, and of the cylinders of porous porcelain. These are represented as occupying a mean position between the zinc and copper. The charge of the apparatus and rationale of its operation, is the same as that already stated in reference to the constant battery in its original form.

405. I do not believe the effects of any apparatus constructed upon this plan, to be at the outset as powerful or striking as those which are producible by a deflagrator of a like extent of surface. Still less would it be possible to comprise a series of like degree of power within a space equally small. A series of two hundred pairs of sustaining batteries would be extremely unwieldy and cumbrous. It

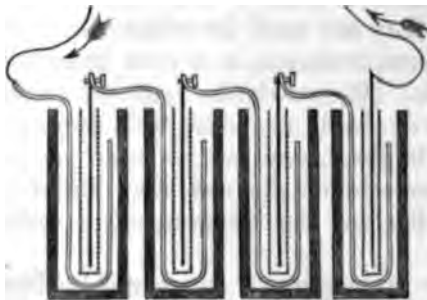
as been mentioned that the construction of the deflagrator such, as to enable me to withdraw four plates out of any five, so as to have the whole accessible to a scraper. Moreover, the amalgamation of the zinc surfaces, devised

Sturgeon, confers upon the plates of the Cruikshank construction, to a certain extent, the properties of a sustaining battery. The great objection, to the somewhat costly use of mercury, is, that it enfeebles the zinc plates so to make them liable to fracture; but this is less to be apprehended when the zinc is supported by corresponding copper plates, as in pairs of the kind above designated, and where the mercury, as in these pairs, is to be applied only one of the surfaces of each zinc plate.

#### *Of Grove's Sustaining Battery.*

106. About the year 1840, Prof. Grove made a very interesting modification of Daniell's battery, not only by substituting vessels of porous porcelain for the ox gullet, but also by using platinum and nitric acid in lieu of copper and a solution of the sulphate of that metal. The porous vessel, nearly full of nitric acid, is surrounded by zinc immersed in sulphuric acid diluted with only four parts of water, contained in a sufficiently capacious receptacle. The nitric acid, by oxidizing the hydrogen, accelerates the electrolysis, nitric oxide is evolved at the surface of the platinum, which is made to occupy an intermediate position within the porcelain cell.

Fig. 19.



107. The dark central lines (figure 19) represent sections of the platinum plates; the dotted lines C, which include these, represent the hollow cylinders of porous

celain. The double lines, which comprise both of those already mentioned, represent sections of the zinc cylinders. The dark external lines, in like manner, represent the glass jars within which the rest of the apparatus is situated. The arrows indicate the course of the current flowing externally agreeably to the general law, from the metal less susceptible of erosion, to that more susceptible; while conveyed internally by the electrolytic process, it takes the opposite course so as to complete the circuit. (306).

408. A series of this kind of only four pairs, constructed in my laboratory, caused the long continued ignition of about two inches of platinum wire. According to Prof. Grove, a series of one hundred pairs, each of the same dimensions as those above described, caused a disruptive discharge, accompanied with intense heat and light, through an interval of three inches, which is as much as was effected in this way, by the great battery of two thousand pairs with which Davy operated at the Royal Institution.

409. Latterly it has been found that plumbago or coke may be substituted for platinum in Grove's apparatus. This material was resorted to independently both by some German chemists, by Prof. B. Silliman, Jr. and myself. An extensive series was constructed for the Lowell Institute, by Prof. B. Silliman, which was very powerful, and had the advantage over the deflagrator of a much more durable intensity of action. In practice, however, there are several objections to Grove's apparatus. The separate introduction of sulphuric and nitric acid into a great number of receptacles in a much more concentrated state than that in which they are used for other voltaic series, as well as the subsequent removal, is a very troublesome and disagreeable task. Moreover, the fumes of nitric oxide which are copiously evolved, are extremely annoying to all persons exposed to them, and are to some persons insupportable. The porcelain cells are very liable to be broken, and soon suffer by the disintegrating influence of the acids.

410. In an arrangement suggested by Berzelius, a cylinder of coke is hollowed out into the form of a cup, into which the nitric acid is placed, and thus the use of an earthenware diaphragm is avoided.

411. A great difficulty arises from the expensive neces-



sity of employing platinum as the material of the screws and wires, by which the requisite attachments are made in batteries formed by the aid of carbon, as above described. Any other metal, excepting gold, which is three times as dear as platinum, is liable to be corroded by the nitric acid, which rises in the carbonaceous pores, by capillary attraction.

### *Of the Passive Iron Battery.*

412. The battery thus designated, was first suggested by Mr. Hawkins (L. and E. Phil. Mag. Vol. XVI.), in consequence of the previous discovery by Herschell, Schoenbien, and others, of the susceptibility of iron of what is called the *passive* state, which renders it insusceptible of being acted upon by strong nitric acid; whereas, in its ordinary state, it is oxidized and dissolved in that acid. The passive state does not protect the metal from acid of the s. g. 1.2. This state of iron is induced by the contact or association with platina, of which, being highly electro-negative, the presence by analogy with copper and zinc should promote reaction with corroding reagents (321). The passive state also protects iron when exposed to diluted sulphuric or phosphoric acid, but cannot avail against chlorohydric acid.

413. This phenomenon is one of the most mysterious, but it is not expedient now to enter into any discussion respecting the cause. The object is to mention the use made of this wonderful property. As the inactive condition is spontaneously assumed when iron is plunged into acid of s. g. above 1.35, a plate of this metal has been substituted in a Grove's battery for the platina plate. According to the authors above named, batteries thus formed were found to be efficient; but, unfortunately, the peculiar condition of the iron is liable to cease. When this happens the rapid solution of the negative plate follows.

414. Schoenbien mentions the formation of batteries either of zinc and passive iron, or altogether of iron cylinders, one set being passive, the other in the normal condition. Five cast iron cylinders, 10 inches high,  $3\frac{1}{2}$  diameter; as many of zinc of same height, and  $3\frac{1}{2}$  in diameter. Intermediate between the zinc and iron, porous cylinders of earthenware, one part nitric, s. g. 1.4, with from twelve to three parts sulphuric acid, were found to

answer. Subsequently, cylinders of iron, in its ordinary state, were substituted for zinc cylinders. By this battery, 2400 cubic inches of the gaseous elements of water were liberated in one hour.

415. It seems, however, that the passive condition of iron is liable to cease, and when this happens, the metal is dissolved. I am under the impression that batteries of this kind can never be found advantageous, as, independently of the uncertainty arising from the precariousness of the passive state of iron, this metal is very liable to be injured by rust when out of use.

### *Of Smee's Battery.*

416. About six years ago, Mr. Smee, of London, discovered that the efficacy of a battery, made like calorimeters or deflagrators (324, 375), Babbington's apparatus (367), or one of his own contrivance, in which a thin sheet of silver is situated between two plates of zinc, may be augmented by a deposition of platina sponge being made upon the surface of the negative metal. For this purpose, platina, palladium, silver, or plated copper, may be used; but, taking both efficacy and economy into view, silver, rolled very thin, was found preferable.

417. In the case of a constant or sustaining battery, (398) it has been stated that the oxidizement of the hydrogen at the diaphragm, obviating the necessity for its evolution in the gaseous form at the cathode, facilitates the electrolytic part of the electromotive process in a galvanic circuit. In Smee's apparatus, the extrication of the hydrogen at the cathode, is alleged to be facilitated by the mechanical power of the asperities of the platinizing deposition. I infer, however, that the contact of the platinum may have a favourable polarizing influence on the hydrogenous cathion, promoting its separation from the other element of water, analogous to that exercised by the same metal in the gas battery (393-4).

418. The following directions are given for platinizing the plates: "Each piece of metal is to be placed in water, to which a little dilute sulphuric acid, and nitro-muriate of platinum, is to be added. A simple current is then to be formed by zinc placed in a porous tube with dilute acid: when, after the lapse of a short time, the metal will be

coated with a fine black powder of metallic platinum. The trouble of this operation is most trifling, only requiring a little time after the arrangement of the apparatus, which takes even less than the description. The cost is about 6*d.* a plate, of 4 inches each way, or 32 inches of surface. It is necessary to make the surface of the silver rough, by brushing it over with a little strong nitric acid, which gives it instantly a frosted appearance, and after being washed, it is ready for the platinizing process; but the finely divided platinum does not adhere firmly to very smooth metals."

## OF THE PHENOMENA OF GALVANISM.

*Under this head we may put effects upon the animal organs, statical effects, ignition of continuous conductors, deflagration, electrolysis or decomposition, galvanic powers and effects of animal organs, magnetic influence or electromagnetism, galvanic effects of heat, or thermo-galvanism, sometimes called thermo-electricity, or thermo-magnetism.*

### EFFECTS UPON ANIMAL ORGANS.

*Effects on the Organs of Taste, on those of Sight, Nerves of Sensation; in producing Convulsions.*

419. Electricity is not the only one among the supposed imponderable elements, which can cause sensation. The influx and efflux of caloric produces a sensation in one case of cold, in the other of heat; moreover intense light, like that of the sun, of galvanic ignition, or the oxyhydrogen lime light, produces in the eyes a painful feeling. But in giving shocks to live animals, and in causing muscular movements or convulsions in a carcase or corpse, electricity has a peculiar attribute.

420. Probably the first knowledge of the shock produced from a galvanic circuit, arose from experiencing that given by the torpedo and other electrical fishes. This wonderful faculty could not but have been observed in the most ancient times by fishermen in the countries where such animals are found.

421. A very feeble discharge like that between a zinc and silver disk, including the tongue, has been felt from the

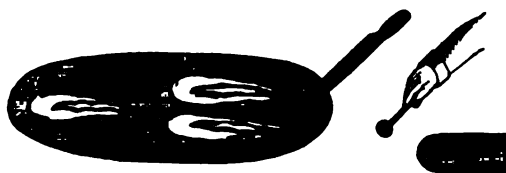
earliest period at which wine, cider, or beer of any kind, was drunk from a metallic vessel. The preference given to pewter as the material of a mug from which to drink beer, is now ascribed to a galvanic discharge arising from the metal, the lips and the beverage, forming a feeble galvanic triad, in which the liquid is electropositive, being slightly acidulous. Probably from an analogous cause arises the characteristic taste of acids, while from an opposite galvanic discharge in which the solution is electropositive, arises the peculiar savour of the principal alkalies. I am inclined to the idea that all the various tastes and odours, which we are liable to experience, are due to modifications of galvano-electro-chemical causes.

422. But the first recorded notice of the phenomena of a galvanic discharge, as respects its obvious production by a metallic triad, was published not as associated with a theory directed to the explanation of physical phenomena; but on the contrary, in a metaphysical effort to suggest a theory of pleasures. In the year 1767, more than twenty-three years before the convulsions produced in frogs by metals was noticed by Galvani, Sultzer, the author of the theory of pleasures alluded to, gave an account of the taste produced by heterogeneous metals, when including the tongue, and brought into contact at their projecting extremities.

423. It must be evident that the original observer of the phenomenon, thus described by Sultzer, was the discoverer of the elementary galvanic battery; and it is remarkable that Galvani was led to infer the existence in nature of the powers of such a battery, by a phenomenon which had no connexion therewith. The hind parts of the carcases of some frogs, prepared for stewing, happened to be situated in a dish, one of them in contact with a scalpel, near an electrical machine, from the prime conductor of which sparks were proceeding. Under these circumstances it was observed, that every spark was followed by convulsive motions in the limbs in the vicinity of the scalpel. The effect was greatest in any limb to which the scalpel might be most approximated. The annexed figure will convey an idea of the manner in which the frogs were situated, relatively to the scalpel; and likewise to the conductor of the machine and knob, between which the sparks were thrown. Galvani was absent, and was in-

debted for his knowledge of the fact to Madam Galvani, by whom it was noticed.

Fig. 20.



424. The convulsions thus observed, it is now known, were the consequence of the limbs and the scalpel being inductively electrified. It is by an analogous inductive influence, that when one person is struck by lightning, bystanders are stunned, though not in the circuit. Electrical discharges deleterious to human life have been attributed to an inductive charge and discharge consequent to lightning, and analogous to those which convulsed the frogs. (See Dynamic Induction.)

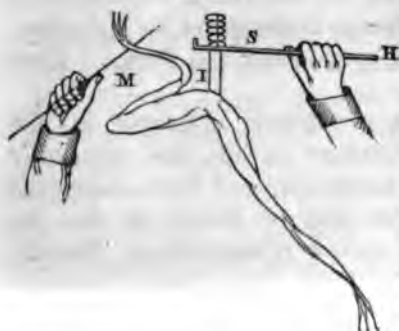
425. Galvani having been previously engaged in the experiments, to verify a conjecture of his, that muscular action is due to electricity, became inspired with additional zeal by these facts, for a knowledge of which he was indebted to accident and his wife's observation. Nevertheless, he would have attributed little importance to the convulsions produced in the frogs, had he not erroneously supposed that the animal organs were instrumental in the generation of the electricity by which they were affected.

426. But, as already stated, (309) the limb of a frog, with the spinal nerves denuded, is a most sensitive galvanoscope, since the minutest discharge of electricity through a circuit of which the nerve forms a part, will produce convulsions in the rest of the limb. Of course during their exposure to the alternate charging and discharging of the machine, the frog limbs acted merely as galvanoscopes.

427. It was, however, subsequently ascertained by Galvani, that convulsions ensue, on making a conducting communication by a metallic wire between the feet of a frog and a portion of the spine appended thereto by the denuded nerves (309). This he correctly ascribed to a power in the parts of the animal to generate electricity;

but erroneously supposed that there was any analogy between the mode of its previous existence, and that of the charge of a Leyden phial. This view of the subject was not unreasonable at a period when no knowledge had been obtained respecting the electrolytic process, by which the current in a galvanic circuit is generated. But the investigation was rendered complicated and perplexing, by the fact, that galvanic discharges causing convulsions are producible in three different ways, of which only the last described is due to the animal organs. Now, it is known the leg of a frog may be convulsed, not only as above described, by a *metallic* communication between the spinal nerve and the feet, but likewise by bringing those parts into contact without the intervention of a metal.

Fig. 21.



428. Figure (21) will illustrate the mode by which the leg of a frog being made to touch the spinal nerve, convulsions will ensue in consequence of an inherent diversity as respects electropolarity in the different parts of the animal.

429. The dissected frog limbs are suspended by means of a glass rod, H, held by the hand at one end, while the other is situated between the two partially denuded nerves of the spine, a portion of the latter, *s*, which is retained, serving to keep them united. By means of another glass rod, M, one of the legs is brought at I, into contact with a nerve. By these means the limbs may be sensibly convulsed. The previous immersion of the limbs and nerves in brine, is recommended by Sturgeon, as rendering success more attainable; but there seems to be some objection to the assistance of an inorganic reagent in an experiment intended to prove that the organs employed are *per se*, equivalent to a galvanic triad or elementary battery: it is nevertheless certain that much more active convulsions may be produced by the discharge from the most minute galvanic triad or the smallest spark arising from the friction of an electric (E, 211). Where a prepared frog is made, like the tongue in the experiment of

**Galvani**, to perform the office of the liquid reagent in a galvanic triad such as above mentioned, the slime of the animal takes the place of the liquid, and the muscles included are convulsed by a discharge analogous to that by which the tongue is affected by the appropriate sensation.

430. Resting his inferences upon the superior efficacy of extraneous sources of electricity, Volta succeeded in creating an almost universal impression, that the idea of a current originating in the organs of frogs had been erroneous. This impression was strengthened by the, subsequently discovered, surprising energy of his inorganic pile in effecting ignition and chemical decomposition.\*

*Of the Diversity in the Sensations produced in the Human Frame by variations in the size and number of the Galvanic Pairs employed.*

431. The different modes, as respects size and number, in which galvanic apparatus may be diversified, has been alluded to. It was soon found that the shock given to the animal frame was increased more by the number, than by the size of the plates. I have found the shock from two hundred and eighty triads, each two inches square, more severe than from one hundred, nearly eight by fourteen or sixteen times as large. The sensation from the latter is more excruciating, if the contact be sustained, because the quantity is so much more copious; but after repose, the poles of the more numerous but smaller series becomes as much greater than the other as twenty-eight is to ten. This greater intensity enables the charge to act more suddenly, and thus to produce the jerking sensation, usually called a shock, in a much higher degree. Davy mentions that severe shocks were received from his large pile through the floor upon which it rested. I have experienced shocks in like manner, when the floor on which a series of three hundred pairs rested, was wet.

\* Under these circumstances, injustice has been done to Galvani, by designating the branch of science originating in his investigations as voltaic electricity. In *Ure's Chemical Dictionary*, so much of the phenomena of this branch as are associated with experiments on recent carcasses, whether of cold or warm blooded animals, are treated of under the head of galvanism, while the other phenomena are treated of under that of voltaic electricity. It appears to me, that galvanism or galvanic electricity, should be known under the general appellation, and that sufficient justice will be done to the other celebrated inventor, if we speak of the compound circuit, as the voltaic series, pile, or battery. The appellation, voltaic series, seems to be preferable, being most descriptive, since whatever may be its construction, it must consist of a series of elementary batteries.

432. Even with closed eyes an ideal flash of light is produced in the Sultserean experiment. According to Sturgeon, it is best executed when one of the pieces of metal employed is pressed close upon the gums beneath the upper lip, the other on the tongue. This preparation being made, a flash is produced by bringing their extreme edges into contact. To enhance the effect, the application of brine to the tongue is recommended. It should be understood that the taste endures so long as the contact continues, but the affection of the optic nerve and the slight quivering of the tongue are transient effects, attendant on the peculiar intensity of the discharge which takes place when the circuit is first completed.

433. To a cut sufficiently deep to draw blood, the most feeble galvanic discharge is perceptible; and that of an extensive battery is excruciating. On the back of the hand, from the comparative delicacy of the epidermis, and the superior conducting power of the veins, the sensibility to galvanic discharges is much higher. Moistening the skin, more especially if any saline solution be employed, causes such discharges to be much more difficult to bear. One of the best modes of taking the shock is to connect each electrode with a cup of mercury covered by water. Dipping a finger of the right hand in one, and of the left in the other, the shock will be felt in perfection. However large the plates of a voltaic series, they cannot produce any perceptible effect until the number of them, made to operate on a conductor, is sufficient to cause a discharge through it. Hence, they may cause the deflagration of a wire, when they cannot give a shock to an animal nor decompose any chemical compound. When a number competent to effect a passage is employed, the shock is not as much greater in proportion to the size of the plates as might be expected, just as in passing a needle through a muscle, our suffering would not be much increased, although, by doubling the diameter of the instrument, we should quadruple its bulk.

434. The sensation created by a comparatively small number of large pairs is more incessant, less jerking, and becomes intolerable from a sensation like the boring of a hot iron. This burning sensation is not surprising, when it is considered that fluids grow hot under the influence of such a series. In 1839, I assisted in some experiments on



**The** corpse of a recently hanged murderer, of whom the **muscles** of the face and those on which respiration is **dependent**, were made to act. I then observed that **ignition** took place whenever the lifting of the end of either **wire** acting as an electrode, caused an interruption of the **circuit**. The series employed was a deflagrator of three **hundred** pairs of seven by three.

### *Of the Statical Effects of Galvanism.*

**435.** It will be well to remember, that under this designation are placed those phenomena of galvanism which, although extremely feeble as to comparative intensity, still resemble the phenomena of frictional electricity as respects **the** spark, the separation and approximation of light **bodies**, and the charging of the Leyden phial.

**436.** Of all the phenomena of galvanism, only those of a **statical** kind are to be produced when the circuit is **incomplete**; and it is under these circumstances, and others **which** are inconsistent with the other powers, that those **in** question appear to most advantage. It is only on **breaking** contact that galvanic apparatus, in the usual **forms**, will produce a spark. If we attach a metallic mass **to** one pole of a galvanic battery, and after bringing into **contact** with it the end of a wire, rod, or strap of metal, in **due** connexion with the other pole, suspend the contact, a **spark** ensues; yet none can be perceived on renewing the **contact**.

**437.** Sparks arising from the rupture of the circuit are **advantageously** seen, by attaching to one of the electrodes a **rasp** or a ratchet wheel, which is so situated as to touch a **spring** strap in due connexion with the other electrode. **By** scraping the rasp with the strap, or if a ratchet wheel **be** used, causing it to revolve against the strap, a spark **occurs** as often as the strap passes from one tooth to **another**. The spark may be produced by metals, which, **like** gold and platinum, are difficult to oxidize, but is larger and more brilliant when iron, steel, or mercury, is used. **Of** these metals, minute portions are mechanically abraded, the combustion of which **coöperates** in the production of **intense** light and heat.

**438.** The phenomenon which, when produced by the **puny** apparatus of man, we call a spark, is designated as

lightning, when evolved by the gigantic apparatus of nature. In no respect are the powers of galvanic batteries more discordant with those of electrical machines than as respects the spark. By electrical machines of the largest size, sparks of from twenty inches to two feet have been emitted: from a very small one, they may be obtained sometimes two inches in length; yet, *before* contact, the most powerful voltaic batteries could not, by the most ingenious and skilful efforts of Gassiot, be made to give any spark; and, according to Davy, the battery of the Royal Institution, comprising thirty-two thousand square inches of zinc surface insulated by porcelain, did not give a spark at a greater distance than one-fortieth of an inch (368). It follows, that to give a spark at ten inches, or four hundred times as far, would require a striking power which would be to that of Davy's series as the square of four hundred to that of one; so that the striking power of a machine giving such a spark must be one hundred and sixty thousand times as great as that of the celebrated battery above mentioned.

439. With insulated voltaic batteries of 1626 pairs made by Crosse, and of 3520 pairs made by Gassiot, excited by river water, sparks were obtained before contact. From the last mentioned battery we are informed that a current of them was obtained. The other powers of the battery are enfeebled, in proportion as its statical power is strengthened.

440. An engraving and description has been given of the dry pile of De Luc, as modified by Zamboni. According to Daniell, when a wire proceeding from one pole of a pile of 20,000 pairs, was drawn lightly over a varnished metallic surface communicating with the other pole, a series of minute sparks were obtained. A Leyden battery might be so charged as to produce a disagreeable shock extending to the elbows and shoulders (378).

441. It does not appear to me that sufficient consideration has been given to this form of voltaic apparatus by the advocates of the purely chemical origin of the galvanic current. Faraday, the matter of fact, Ajax of that corps, insists on the necessity of a species of electrolytic convection between the zinc and copper surfaces, to the conveyance of the current. He urges the necessity of a process like that which is supposed to take place during the decom-

sition of water between the electrodes (395). It cannot be pretended, that any such electrolytic series of decompositions can go on by means of the minute and detached particles of hygrometric water contained in the paper material of Zamboni's disks: and admitting that moisture, thus existing, could, by its electrolytic decomposition, be adequate to sustain the electrical discharges for years (381), by what process is it transferred from surface to surface through the intervening paper? Evidently it cannot be conceived to pass by the series of decompositions and recompositions in rows of the atoms of an intervening liquid. Sturgeon avers, that the powers of De Luc's series is greater in proportion as the surfaces are kept brighter, so that chemical action, far from being necessary, is actually injurious to the energy of the apparatus.

### *Of Continuous Ignition.*

442. I deem it expedient to distinguish, under the general designation of continuous ignition, those cases in which a body, to be ignited, is a good conductor (a wire or charcoal, for instance), forming that part of the galvanic circuit which lies between the electrodes (356). In this case a wire being uniform in diameter and shape, the length may be directly as the intensity. The larger the plates, the stouter the wire which can be rendered incandescent: the greater the number of the series, the longer. Within any reasonable limits, the sectional area for a given length may be as the area of the oxidizable surface of one pair; the length as the number of pairs in the series.

443. By the gigantic apparatus of Children, a platinum wire, five feet six inches in length, and more than one-tenth of an inch in diameter, was heated red-hot. By my deflagrator, several feet of wire of the same material may be raised to incandescence, and when consisting of iron, it may be burned by the atmospheric oxygen before fusion.

444. The platinum wire employed in igniting gaseous mixtures (C, 335), is liable to fusion, if care be not taken to break the circuit before the temperature reaches its maximum.

445. It is remarkable that if the wire, subjected to continuous ignition, be of uniform thickness, as is usually the

case with a wire in good preservation, the ignition begins about the middle, and extends gradually towards the electrodes.\*

446. If a prism of well-burned charcoal be made to connect the poles of a powerful deflagrator, on completing the circuit, by bringing the plates and acid into contact, the charcoal will be instantaneously ignited throughout.

*Of the Ignition of a Continuous Conductor by a Calorimotor or Deflagrator.*

447. If the electrodes of a galvanic triad, of the construction to which the name calorimotor has been given, be united by a wire before the immersion of the plates; on immersing them, the wire will be more or less heated, according to the extent of the oxidizable metallic surface, and the size and length of the wire; excepting that the intensity produced by one pair lessens as its size is enlarged. Although on estimating the heat which it can produce, in wire of a certain magnitude, it may be found in quantity proportionable to the size, in order that this proportionable quantity may appear, the wire must have magnitude too

\* As, when the wire is of a sufficient length, it takes some time for the whole to become incandescent, and as fusion cannot be effected in the central portion so long as the rest of the wire is below a white heat, the operator is enabled to avoid fusing the central portion, while raising it, nevertheless, to the highest temperature which platinum will bear. To effect the combustion of hydrogen with nitrous oxide, requires a heat so intense, that I always use a wire for that purpose of nearly two inches in length, and of about No. 26 of the wire gauge.

An argument in favour of the theory of Dufay has been founded upon the idea, that the heat taking place midway, corresponds with the meeting of two fluids at an intermediate space within the circuit equidistant from their respective sources. But it should be kept in mind, that agreeably to the theory of two fluids, the negative end of the pile has to receive as much vitreous as it yields up resinous, and the positive end has to receive as much resinous as it emits of vitreous electricity.

It follows, that the conditions necessary to electric activity, agreeably to that theory, consist in the simultaneous motion of two fluids in opposite directions. It cannot consist in their coming together at any particular part of the circuit more than in any other. It is true, that when the circuit is interrupted, an excess of vitreous electricity will be accumulated towards the positive end of the series, and an excess of the resinous towards the negative end; but, on completing the circuit, commensurate with the discharge of the vitreous accumulation into the anode will be a discharge of the resinous electricity in the opposite direction. In like manner, commensurate with the discharge of the resinous into the cathode will be an opposite discharge of the vitreous. The fluids are necessarily in motion throughout the circuit, to restore the equilibrium which the electro-chemical reaction is necessarily destroying.

The phenomenon under consideration, though irreconcilable either with the theory of one or that of two fluids, agrees with the idea of waves of polarization moving from the centre of the generating battery towards the extremities, thence passing through the metallic conductor to neutralize each other at an intermediate point in the wire. Possibly each wave, carrying with it caloric in a latent state, may yield it up when, by neutralization, the power to retain it ceases; and thus may arise the heat evolved at the place of meeting, so long as the current is sustained.

great to be consistent with intensity. Hence, a more intense heat may be produced in a fine wire by a triad of a square foot of oxidizable surface than by one of fifty. On this account it is necessary in a very large calorimotor to employ more than one triad in order to produce a white heat in a wire whether stout or fine\* (331).

### *Of Deflagration.*

448. Those experiments in which the contact or continuity of the conductor between the electrodes, after being established, is destroyed by its reaction with the current, or by the interference of the operator, fall under the head of deflagration.

449. Thus when suitable tapering pieces of charcoal, severally attached to the electrodes of an active and sufficiently powerful series, after being brought into contact, are separated, the resulting interval becomes occupied by an arc of flame of which the light and heat are the most intense that art can produce. It is not without pain, and the risk of permanent injury, that this flaming arch, or

\* For more than twenty years, I have employed calorimotors for effecting the explosive combustion of gaseous mixtures, or for igniting a jet of hydrogen in oxygen in the Lavoisierian experiment for the synthesis of that liquid (834-5). In such experiments, that distinguished philosopher, and generally all the chemists of the old world, have used for the same object, the electric spark. This it is difficult to command in damp weather, and in the vicinity of the water usually employed in pneumatological experiments.

In June, 1831, I was induced to make a series of experiments, in order to explode the charges of gunpowder in rock-blasting, and succeeded by one of my deflagrators in exploding twelve charges at the distance of one hundred and fifty feet. Of these experiments, I published an account in 1833, in the Franklin Journal, and recommended this process as peculiarly well suited for blowing up fortifications and blasting under water.

In England, about five years afterwards, efforts having been unsuccessfully made by other means of ignition, to remove the wrecks of vessels by the explosion of gunpowder previously introduced into their holds, galvanic ignition was resorted to pursuant to my suggestion. Nevertheless, upon the plea that my apparatus had not been employed to affect ignition "under water," resort was had to another, which was of course, previously to trial, amenable to the same objection. In fact, the deflagrator was peculiarly competent to effect ignition under water, far more so than the constant battery which was used. This arises from the completion of the circuit being effected by throwing the acid on the plates at the moment when the ignition is required. In this mode of operating, a transient power may be obtained far greater than can be had from an equal extent of surface in a constant battery.

Finally, however, Col. Paisley succeeded in blowing up the wreck of the Royal George, by means of galvanic ignition. Since then, a person by the name of Colt, has applied the process of galvanic ignition so successfully, as to blow up a vessel at the distance of several miles from the battery employed. In the employment of this process, it does not appear, that he made any due acknowledgment either as to Col. Paisley or myself. So entirely was the committee of congress with whom he conferred, in the dark, that in April last, both Prof. Joseph Henry, of Princeton, and myself, were applied to, by the Secretary of War of the United States, to give that information, which it was evidently Colt's duty to have given at the outset.

the bodies exposed to it, can be viewed by unprotected eyes.\*

450. On comparing the light thus generated from nine hundred pairs of seven by three inches, with that of a candle, the ratio appeared to be as sixteen hundred to one. The shadow of the whiskers, or of a prominent lock of hair, partially intercepting the light, was cast upon a wall with extraordinary accuracy. The side of an adjacent house, on which the rays fell in the night, appeared as if illuminated by the sun.

451. When a rod of platinum, of a quarter of an inch in diameter, while attached to one pile, was made to touch charcoal attached to the other, the instantaneous fusion of the platinum at the point ensued. A knitting needle substituted for the rod of platinum was explosively deflagrated. In such cases the wire is destroyed in detail, the combustion being limited to the vicinity of the end. For this and other deflagrations where a metal is in question, it answers better to have one charcoal electrode, than to have both of metal. Two metallic electrodes are liable to be soldered or welded together. The incorporation thus arising, takes place even under water. A platinum wire brought into contact with an iron rod under water may be welded thereto. It is preferable to have one wire always stouter than the other. Of course tin-foil and other leaf metal are rapidly deflagrated by the same process as the knitting needle. A jet of mercury, so regulated as not to form a stream quite continuous, being made the medium of the discharge of a deflagrator, a splendid effulgence ensues, arising from the combined effects of the combustion of the metal and the galvanic light.

### *Deflagration with Liquids.*

452. Let a concentrated aqueous solution of chloride of calcium be first brought fully into contact with a stout platinum wire, acting as the positive pole of a deflagrator

\* On one occasion, after making some experiments with an extensive series, my eyes were so much affected, that all other flame appeared of a deep blood-red, and on the following day they were blood-shot, and so greatly inflamed, that it was deemed expedient to apply twenty leeches to each to procure relief.

On another occasion, similar consequences ensued to an assistant, who was not deterred from subjecting his eyes injudiciously to an ordeal like that which mine had undergone.

f about three hundred pairs, seven inches by three, in full operation. In the next place, let a platinum wire of about No. 30 of the wire gage, acting as the negative pole of the same series, be allowed barely to touch the solution, the most intense ignition will ensue, causing the platinum to be fused rapidly into globules, which will be found at the bottom of the solution. An analogous result ensues with other saline solutions, if capable of a similar degree of density. The fusion of the platinum, however, is much more readily effected with the chloride of calcium. This, I infer, arises from the extrication of the calcium, its union with the platinum momentarily, and subsequent rapid combustion by the oxygen of the water.

453. It is remarkable that this experiment could not be performed by a deflagrator of one hundred pairs of seven and a half by fourteen, although succeeding perfectly with three hundred pairs of seven by three, having less than two-thirds of the surface disposed in a series of an inferior number.

454. There is no mode by which a small portion of a substance can be subjected to heat in the absence of the oxidizing influence of the air, or with the co-operation of the deoxidizing affinity of hydrogen, so powerfully, as that of a large voltaic series acting in a receiver capable of exhaustion and replenishment with that gas or any other. Subjecting phosphuret of lime in this way to the intense ignition produced by two hundred pairs, each of nearly seven and a half by fourteen, I reduced the calcium very nearly to a state of purity, as a small portion acquired a metallic brilliancy under the burnisher, and decomposed water rapidly on being thrown into it.

455. Having, in like manner, exposed cyanide of calcium, the result was similar, but less exceptionable, as this compound does not possess the property of liberating hydrogen from water, so that the acquisition of the property indicated more certainly that the substance evolved was calcium. In either case lime was found in the water, in which the supposed calcium had been immersed.

*Of the Electrolytic Power of Galvanism, or Galvanic Power of Chemical Decomposition.*

456. The voltaic series was first discovered to have powers of decomposition, or electrolysis, by Nicholson and Carlyle. These ingenious investigators found, on subjecting water to copper wires acting as the electrodes of a voltaic pile, that while hydrogen was evolved at the negative electrode, the positive electrode was oxidized. But when wires of gold or platinum were used, both of the gaseous elements of water were evolved. In the following summer I was invited by my predecessor, Dr. Woodhouse, to see the experiment then going on in his laboratory, by means of a series constructed of disks of copper, zinc, and moistened cloth. This was considered as a great step in science at that time, when it was still denied that water could be decomposed, or that the hydrogen obtained by passing it in the state of steam over incandescent iron, was an element of that liquid. To the evolution of its gaseous elements by the voltaic pile, those who considered it as a compound, appealed with elation; and the proofs that it could be thus *electrolysed*, as we would now say, were finally such as to silence all who had been incredulous.\*

\* *Engraving and Description of an Apparatus for the Decomposition and Recomposition of Water, employed in the Laboratory of the Medical Department of the University of Pennsylvania.*

Having to illustrate the decomposition and recombination of water to a class of between three and four hundred pupils, I have found it expedient to exhibit the process on an extensive scale. Hence, for many years, I have employed a glass tube of about two inches in bore, and about two feet in height, furnished with two tubulures, B, b, about three inches below the upper extremity, where the bore converges to an apex, having an aperture not larger than a goose quill. Upon this apex there is an iron cap, in which a female screw is wrought so as to allow a large iron valve cock, C, to be screwed into it.

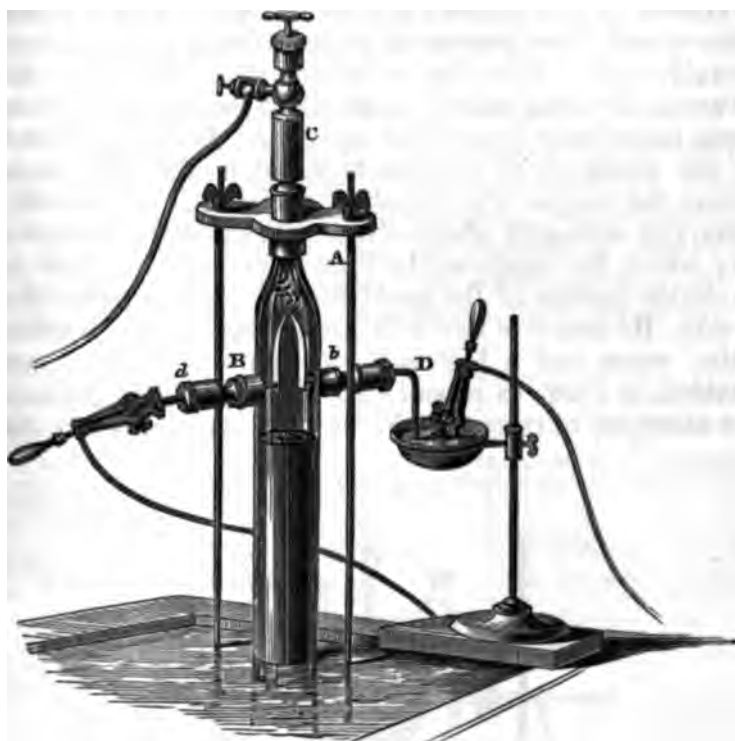
Upon the tubulures iron caps are cemented, which are so wrought, as, with the aid of appropriate screws, to constitute stuffing boxes. Through each of these a platinum rod, D, or d, is introduced, and fastened to plates of platina, to act as "electrodes," agreeably to the language of the celebrated Faraday.

The tube being supported over the mercurial cistern, by means of a communication with an air pump through the valve cock and flexible leaden pipe, the bore of the tube is exhausted of air, so as to cause the mercury to take its place. The mercury is so far displaced by a solution of borax, consisting of equal parts of water and a saturated solution of that salt, as to sink the surface of the column of metal in the tube about an inch or more below the "electrodes." The projecting end of one of the rods, D, d, to the other ends of which the "electrodes" are severally attached, is bent at right angles outside of the tube, so as to enter some mercury in an iron capsule, supported purposely at a proper height, and communicating with one end of my deflagrator of an hundred pairs of Cruickshank plates, described page 22. Of course the rod of the other electrode must have a communication with the other end



457. In 1807, Davy made the grand discovery of the composition of potash and soda, by means of two hundred pairs

Fig. 22.



of the deflagrator. Under these circumstances, if the circuit be completed by throwing the acid on the plates of the deflagrator, a most rapid evolution of hydrogen and oxygen will ensue in consequence of the decomposition of the water, so that within a few seconds, several cubic inches of gas will be collected.

The action being now suspended by throwing the acid off the plates, and the foam being allowed to subside, the resulting gaseous mixture may be ignited, and of course condensed, by completing the circuit again as at first, and at the same time causing the ends of the "electrodes" to come into contact with each other, and thus to produce a spark. This contact is effected by causing a very slight movement in the rod, bent at right angles, and entering the mercury in the iron capsule. Of course the process may be repeated as often as can be reasonably desired.

*Generation of the Amalgam of Ammonium, upon a large scale, by "Electrolization."*

An open necked bell, A, inverted and supported as in the figure, is furnished with a plug, P, by which the orifice in the neck may be closed or opened, more or less, as desirable. The lower part of the cavity of the bell is occupied by mercury, covered by a stratum of a concentrated solution of chloride of ammonium (sal ammoniac). An iron wire, W, so covered with gum elastic, as to pass through the solution of chloride without any conducting contact, establishes a communication between the mercury and the negative pair of the series. By means of a platina strap, S, a like communication is effected between the positive pole and the dissolved chloride. The circuit being completed, the mercury soon swells up, assuming the well known ap-

of four inch square plates. By Sweiger and Bern analogous results were obtained by using mercury as negative electrode. By the presence of this metal nascent metal of the earth subjected to the process, was a certain degree protected from oxidation, which otherwise would have prevented it from being retained in metallic state. Davy, by submitting the amalgams to distillation, obtained minute portions of barium and sodium, imperfectly deprived of mercury. In the distillation of the amalgam of calcium, he failed, as the tube broke before the process was complete. From my experiments I infer, that with sixty grains of mercury, which was the quantity which he employed, he could not have obtained the available portion of the metal had the process succeeded.

458. By means of two deflagrators, each of one hundred pairs, seven and a half inches by fourteen (375), I was enabled, in 1839, to procure as much as 3600 grains of the amalgam of calcium. From this the mercury was

Fig. 23.



appearance of an amalgam. When a sufficient quantity of this is formed, by loosening the plug, any excess of mercury may be allowed to run out into one receptacle; afterwards the amalgam may be received in another; care being taken to stop the aperture, by means of the plug, before the residual aqueous solution can follow. By these means about half a pint of the amalgam has been obtained. The diameter of the bell, which I have used, is about five inches.

It has been found advantageous to add liquid ammonia to the solution, in sufficient quantity to prevent the evolution of free acid, which seems to destroy the amalgam when in contact with it beyond the influence of the circuit.

tilled, by means of a crucible included in a cast iron alembic, the cavity of the latter having been previously supplied with some pure caoutchoucine to expel oxygen. In this way I obtained sixty grains of calcium. In subsequent efforts I also succeeded in obtaining about the same quantities, respectively, of barium and strontium.\*

### *On Secondary or Indirect Decomposition.*

459. In the case of the decomposition of a liquid by wires, acting as electrodes, it was formerly inferred that the elements which appeared at the electrodes were liberated by a direct electrolytic influence, but Faraday has shown that the evolution of the element of one compound, another compound being present, may cause the decomposition of

\* The cuts having unexpectedly been found to be missing, and not deeming it expedient to stop the press in order to replace them, I have to omit giving an engraving and description of the apparatus employed in the processes above mentioned (444, 456).

As no account of these metals, as procured by me, is given under Inorganic Chemistry, the statements made respecting them in the last edition of this Treatise are subjoined.

#### *Properties of Calcium, Barium, and Strontium.*

When the heat was sufficient to expel all the mercury, the metal was found adhering to the bottom of the crucible in a crust, which required an edge tool to detach it, though no incorporation of the iron with it appeared to have taken place. When in distilling calcium, a crucible of platina was employed, a portion of this metal was found to have united with some of the calcium, being detached therewith in the form of a bright metallic scale.

In consequence of their susceptibility of oxidation, and of union with the elements of naphtha, the metals obtained as abovementioned were devoid of metallic lustre until their surfaces were removed by a file or burnisher. Either was rapidly oxidized in water, or in any liquid containing it; and afterwards, with tests, gave the appropriate proofs of its presence. They all sank in sulphuric acid; were all brittle, and fixed, and for fusion, required at least a good red heat. After being kept in naphtha, their effervescence with water is, on the first immersion, much less active. Under such circumstances, they react at first more vivaciously with pure ether than with water, or even chlorohydric acid; because in these liquids a resinous covering, derived from the naphtha, is not soluble, while to the ether it yields readily.

By means of solid carbonic acid, obtained by Mitchell's modification of Thilorier's process, I froze an ounce measure of the amalgam of calcium, hoping to effect a partial mechanical separation of the mercury, by straining through leather, as in the case of other amalgams. The result, however, did not justify my hopes, as both metals were expelled through the pores of the leather simultaneously, the calcium forming forthwith a pulverulent oxide, intermingled with and discoloured by mercury in a state of extreme division.

By the same means I froze a mass of the amalgam of ammonium, as large as the palm of my hand, so as to be quite hard, tenacious, and brittle. The mass floated upon the mercury of my mercurial pneumatic cistern, and gradually liquefied, while its volatile ingredients escaped.

When the freezing of the amalgam was expedited by the addition of pure ether, the resulting solid effervesced in water, evolving ethereal fumes. This seems to show that a portion of this ether may be incorporated with ammonium and mercury, without depriving the aggregate thus formed of the characteristics of a metallic alloy.

the latter when the element first evolved has a predominant affinity for one of the constituents of the compound to which it is thus presented. Thus the deposition of a metal at the negative electrode from a solution of one of its salts, by exposure to the circuit, may be the consequence of its oxide being decomposed by the affinity of hydrogen in a nascent state as evolved from water. The nitrogen evolved at the anode from liquid ammonia, under like circumstances, is conceived to be liberated by the union of its hydrogen with the oxygen of water directly decomposed.

460. As in the electrolysis of salts of the alkalis and alkaline earths, when mercury is employed as the negative electrode, an amalgam is obtained of the metallic radical of the salt, I had formed the opinion that it is the metallic oxide which is the subject of direct decomposition, and that when hydrogen appears at the cathode it is the consequence of the decomposition of the water by the metal. It is known that as soon as either of these in its metallic state touches water, seizing the oxygen, it liberates the hydrogen of this liquid. Subsequently, I found that Matteucci, a distinguished Italian philosopher, had arrived at the same opinion as myself, on this subject, after performing a series of laborious experiments with a view to ascertain the truth.

461. This question must excite great interest from the fact, that it has an important bearing on the electrolytic investigations recently made by Daniell, which by Kane, Graham, and others, as well as the author of them, have been considered as justifying the salt radical theory. But in either way of viewing the subject, Faraday's suggestions that the elements, which are the ostensible products of the process, may be indirectly evolved, is fully sustained.\*

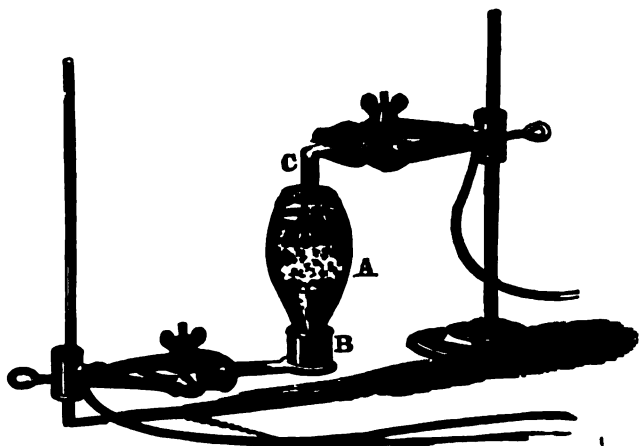
\* Figure 24 represents an apparatus which may be conveniently employed for the electrolytic formation of amalgams with the metals of the alkalis or alkaline earths.

The lower end B of the receiver A is perforated so as to have an iron, or preferably a-platinum wire, so luted therein, that one end may just enter the cavity of the receiver, while the other end is soldered to a metallic strap supporting the receiver, and held by a vice communicating through a wire rope with the positive end of a competent voltaic series. The lower part of the cavity of the receiver is occupied by some mercury, necessarily in contact with the end of the wire already described as entering that space. Upon the mercury a stratum of the aqueous solution containing the desired metal must be situated. By means of a strip of platinum in contact with this solution at one end and at the other held by a vice in communication with the positive end of the voltaic series, the circuit is completed. Upon

*Results obtained by long enduring Galvano-Electric Currents of Low Intensity.*

162. Becquerel and Were Fox, have drawn the attention of the scientific world to processes, in which galvanic currents long continued, of low intensity, have been successfully employed. It has been rendered probable by investigations and observations of Were Fox, that gallic circuits are among the most efficient causes of metallic depositions in mines, and by Becquerel, the processes of nature in the formation of crystals have been imitated. In this path, laborious experiments, of unpremeditated endurance, have also been made by Crosse. It is during some efforts to produce by the voltaic current crystals, and other compounds, analogous to those found in nature, that this zealous electrician observed a species of mite, since called *acarus galvanicus*, to appear. It is certainly miraculous that these insects should come into existence under the influence of agents, which are never intended to enter into the constitution of animals, and which are of a nature to destroy life in the case of animated

Fig. 94.



Under these circumstances, the series being in a sufficient degree of activity, the mercury, acting as the negative electrode separates, and unites with any metallic cathion in the electrolyte held by the solution subjected to the process; meanwhile the anionic electrolyte is evolved at the anode, or where the surface of the platinum electrode is in contact with the liquid (358).

nature in general. The insect so much resembles a cheese mite, that it might be mistaken therefor on a hasty examination.

463. The experiments of Crosse have been repeated, with modifications, by Weekes of the London Electrical Society. This ardent investigator subjected to the galvanic current solutions of silicate of potash, in glass receivers over mercury, the greatest care being taken to guard against the access of any extraneous bodies. Under these circumstances, after an uninterrupted exposure during upwards of a year, insects are alleged to have made their appearance perfectly resembling those which seemed to come into existence during the experiments of Crosse. Mr. Weekes has since asserted that the acari appeared to have originated in a solution of ferroproussiate of potash. The origin of these insects is inexplicable, since it is utterly impossible that they can be *created* by the agents and process employed.\*

\* On this subject, in my Introductory, delivered in 1843, I expressed myself as follows:

A few years since, many of the more inconsiderate among the reading portion of society, were carried away by an account respecting certain experimental observations made by an enthusiastic electrician, to believe in the generation of certain insects through the influence of the voltaic current. It struck me at first, that, nothing less than the miraculous interposition of the Deity could give rise to animal life, this narrative must be a jocular fiction, like the statement respecting certain observations of Herschel, in aid of which the light of the hydro-oxygen blow-pipe flame was employed to co-operate with the solar rays in illuminating bodies, at the lunar surface, at the distance of more than two hundred and thirty thousand miles!

It was, nevertheless, true, that an equivocal description had been given, in good earnest, tending to create the idea that animals had been generated by a voltaic current out of silicious earth, alkali and acid. It subsequently appeared, not that certain species of acari or lice had been created, but that they had been *stimulated* to exhibit themselves by the agents and apparatus employed. According to my apprehension, it had been quite as practicable to repeat the Mosaic miracle of bringing water from a rock, by the blow of a rod, without supernatural aid, as to create sentient organized beings by the materials and apparatus employed by the electrician. Far more reasonable were it to expect the formation of a watch by subjecting the ores of the metals requisite for its construction to the voltaic process.

Perhaps human genius has in no instance approached more nearly to the production of a machine having the attributes of an animal, than in the construction of the locomotive steam engine, of which the furnace may be considered as performing the office of a stomach, the cylinder and pipes that of the bowels, while the shaft, levers and wheels act as limbs; but still the will, the instinct, the power of self-reproduction, and the heaven-born sense of existence, are deficient.

In fact, human efforts have never attained the point of making a self-moving machine, or perpetual motion, however wrong-headed projectors may have deceived themselves and others with false expectations of success in that impracticable project. For, although there be in nature incessant movements, like those of the planets, or of waves, &c., and currents which, originating from calorific, or electric changes, move or flow without intermission from age to age, such sources of motion are not to be created by man.

*Important Inferences of Faraday, respecting Electrolysis.*

464. Among many important services rendered by Faraday, is that of demonstrating that electro-chemical decomposition takes place in equivalent ratio, being always directly as the quantity of electricity which passes by the electrolytic separation and rearrangement of the ions (360). For the investigation of the phenomena dependent on this law, an instrument was devised by him, which, being interposed in the circuit, enabled him accurately to measure the gaseous products of the electrolytic decomposition of water. The result, thus obtained, was assumed as a standard by which to estimate the products of the decomposition of other electrolytes exposed to the same current simultaneously with water. To the instrument thus employed the name of volta electrometer, or by abbreviation voltameter, has been given. The construction of this instrument does not differ essentially from the apparatus above described for the decomposition of water (note to 450), excepting the absence in the latter of graduation, by which the volume of the gas generated is ascertainable on inspection.

465. By means of this apparatus it was ascertained, that when the fused chlorides of tin and lead were either severally or simultaneously subjected to the same active circuit, so that the products of their decomposition might be compared with those of water with water, the weight of the elements evolved from this liquid, collected in the voltameter, and those of the chlorine and metals, liberated from the chlorides, were to each other as their equivalents, H 1, O 8, Cl 36, Pb 104, Sn 59, C (560).

466. By these results, and many others of an analogous character, it seems to have been fully established, that the quantity of any electrolyte which can be decomposed by a galvanic current is directly as the quantity of the electricity which passes through it: moreover, that the weights of different electrolytes decomposed by the same quantity, will be to each other, as the numbers by which their atoms are represented in the table of equivalents. The only motive for increasing the intensity by a numerical extension of the series employed, is that for the passage of the fluid by the electrolytic process, the requisite force must be as the reciprocal affinity of the ions of the electrolyte employed. Thus, as in the chloride of calcium, a stronger affinity is to be overcome than in decomposing the iodide of that metal, a greater number of pairs are required, but the quantity of the compounds in question decomposed, will be, *ceteris paribus*, as the size of the plates, without reference to the number of the series.

467. Not only did Faraday show that the weights of the ions evolved by the same galvanic current from different electrolytes, and consequently the weights of these, were to each other as their equivalent numbers, it was also shown by this skilful experimenter, that to produce the same quantity of electricity from different metals by galvanic reaction, the weights of the quantities corroded, must be to each other as the equivalent numbers of the metals.\*

\* It seems to me remarkable, that under these circumstances, no reference is made by Faraday to the analogous results, obtained by Pettit and Dulong, respecting specific heat. It is well known, that it was rendered highly probable, by these philosophers, that the quantity of heat given out by bodies was equally great for each atomic equivalent. The specific heat of every gas is the same, so that although the weight of equal volumes of gaseous hydrogen and oxygen are as one to sixteen, the quantity

### *An Interesting Summary of Faraday's Inferences.*

The following summary of his inferences is given by Faraday.

468. "i. A single *ion*, i. e. one not in combination with another, will have no tendency to pass to either of the electrodes, and will be perfectly indifferent to the passing current, unless it be itself a compound of more elementary *ions*, and so subject to actual decomposition. Upon this fact is founded much of the proof adduced in favour of the new theory of electro-chemical decomposition, which I put forth in a former series of these searches.

469. "ii. If one *ion* be combined in right proportions with another strongly opposed to it in its ordinary chemical relations, i. e. if an *anion* be combined with a *cation*, then both will travel, the one to the *anode*, the other to the *cathode*, of the decomposing body.

470. "iii. If, therefore, an *ion* pass towards one of the electrodes, another *ion* must also be passing simultaneously to the other electrode, although, from secondary action, it may not make its appearance.

471. "iv. A body decomposable directly by the electric current, i. e. an *electrolyte*, must consist of two *ions*, and must also render them up during the act of decomposition.

472. "v. There is but one *electrolyte* composed of the same two elementary *ions*; at least such appears to be the fact, dependent upon a law that only single electro-chemical equivalents of elementary *ions* can go to the electrodes, and not multiples.

473. "vi. A body not decomposable when alone, as boracic acid, is not directly decomposable by the electric current when in combination. It may act as an *ion* going wholly to the *anode* or *cathode*, but does not yield to its elements, except occasionally by a secondary action. Perhaps it is superfluous for me to point out that this proposition has no relation to cases as that of water, which, by the presence of other bodies, is rendered a better conductor of electricity, and therefore is more freely decomposed.

474. "vii. The nature of the substance of which the electrode is formed provided it be a conductor, causes no difference in the electro-decomposition, either in kind or degree: but it seriously influences, by secondary action, the state in which the *ions* finally appear. Advantage may be taken of this principle in combining and collecting such *ions* as, if evolved in the free state, would be unmanageable.\*

475. "viii. A substance which, being used as the electrode, can combine with the *ion* evolved against it, is also, I believe, an *ion*, and combines in such cases, in the quantity represented by its *electro-chemical equivalent*. All the experiments I have made agree with this view; and it seems to me at present, to result as a necessary consequence. Whether, in the secondary actions that take place, where the *ion* acts, not upon the matter of the

of heat in the equal spaces which they occupy are equal; so that the specific heats of these gases are inversely as their densities or weights. The densities of hydrogen, oxygen, nitrogen, and chlorine, being respectively as 1, 8, 14, 36, the specific heats of equal weights of hydrogen, oxygen, nitrogen, and chlorine, are inversely as those numbers.

\* It will often happen that the electrodes used may be of such a nature as, with the fluid in which they are immersed, to produce an electric current, either according with or opposing that of the voltaic arrangement used, and in this way, or by direct chemical action, may sadly disturb the results. Still, in the midst of all these confusing effects, the electric current, which actually passes in any direction through the body suffering decomposition, will produce its own definite electrolytic action.



electrode, but on that which is around it in the liquid, the same consequence follows, will require more extended investigation to determine.

476. "ix. Compound ions are not necessarily composed of electro-chemical equivalents of simple ions. For instance, sulphuric acid, boracic acid, phosphoric acid, are ions, but not *electrolytes*, i. e. not composed of electro-chemical equivalents of simple ions.

477. "x. Electro-chemical equivalents are always consistent; i. e. the same number which represents the equivalent of a substance A, when it is separating from a substance B, will also represent A when separating from a third substance C. Thus, 8 is the electro-chemical equivalent of oxygen, whether separating from hydrogen, or tin, or lead; and 103.5 is the electro-chemical equivalent of lead, whether separating from oxygen, or chlorine, or iodine.

478. "xi. Electro-chemical equivalents coincide, and are the same, with ordinary chemical equivalents."

479. It is much to the honour of Faraday that these opinions, which were mostly original, appear to be for the most part sanctioned by the scientific world. The greatest error is, as I conceive, in his language being of a nature to convey the idea of a loco-motion, which cannot take place agreeably to his own premises, and which I infer it was not his intention to treat as necessary to the electrolytic process. On this, I have already commented (397). Subjoined are some additional strictures (480, &c.).

*On Sir H. Davy's Experiments on the Transfer of Acids through Alkalies, and of Alkalies through Acids by the Voltaic Currents.*

480. When three vessels A, B, C, were associated by moistened strips of asbestos, so that the intermediate vessel A, held either an acid or an alkali, B, a saline solution, C, pure water, Sir H. Davy found that by making them into a voltaic circuit, either an acid or alkali would reach the water of C. Hence it was inferred that, under the magic escorting influence of the current, an acid ion, as we now call it, might pass through an alkali, or an alkaline ion through an acid. Faraday treats this miraculous result as the natural consequence of the interposition of a body capable of combining with the ion during its journey. It seems, however, inconsistent with his adoption of the Grothian hypothesis (389), respecting the mode in which ions are liberated by the current, that an ion should actually travel. Consistently with that view of the subject, in order that an acid ion should be liberated at the anode, and an alkaline ion at the cathode, there must be a row of compound electrolytic atoms, subsisting between the electrodes, in which the ions evolved are ingredients.

481. I trust that the following quotation from the work of his friend, Daniell, fully justifies my conception of the subject.

482. "We have now to consider how the impulse, which is derived from the zinc, is transmitted through the liquid to the platinum; and how we may account for the extraordinary fact, that the radical of a portion of the acid combines with the former, while the equivalent hydrogen, with which it was associated, is evolved upon the distant surface of the latter.

483. "No visible transfer of the disunited elements takes place, and if the vessel which contains the acid, be divided either by a diaphragm of bladder, a partition of porous earthenware, or other substance capable of imbibing the liquid, and the two plates be placed on its opposite sides, no impediment arises to this extraordinary separation.

484. "The force must be conceived to travel in this part of its circuit by

a species of convection, of which a mechanical illustration again may aid us in forming a just notion. When a number of ivory balls are freely suspended in a row so as just to touch one another, if an impulse be given to one of the extreme ones, by striking it with a hard substance, the force will be communicated from ball to ball without disturbing them, till it reaches the most distant, which will fly off under its full influence. Such analogies are but remote, and must not be strained too far; but thus we may conceive that the force of affinity receives an impulse in a certain direction, which enables the hydrogen of the first particle of aqueo-acid which undergoes decomposition, to combine momentarily with the radical of the next particle in succession; the hydrogen of this again with the radical of the next; and so on, till the last particle of hydrogen communicates the impulse to the platinum, and escapes in its own elastic form."

485. In order to render this resort to balls consistent with the phenomenon which it is intended to enlighten, I conceive, that instead of supposing one row of balls, we must suppose two rows, one parallel to the other. At the same time, it may be expedient to imagine that one row, representing the anions, are white, while the other, representing the cathions, are black; and that they are arranged in pairs, each of which represents a compound atom of the electrolyte. It seems necessary, also, that there should be no impulses given, opposite in tendency, so that one operating upon each row, may cause the expulsion of an anion, at one end, from the white row, a cathion, at the other end, from the black row; the residue rearranging themselves within the same boundaries, so as still to exist in pairs, and to have no unpaired ball at either extremity. Meanwhile it is inevitable, that this loss of an anion and a cathion will be compensated by the access of another pair, of which, to make the analogy hold, there should be an abundance at hand. Moreover, the row, thus refitted, should, under the stimulatory influence of the heat arising from the process, give place to another row, similarly constituted, and equally susceptible of electrolyzation. Thus it follows, from the illustration to which Daniell has resorted, when well carried out, that, consistently with his own explanation of the process of electrolyzation, there can be no travelling of an ion from one electrode to the other. It is alleged by him, that the force travels, per se, by a species of convection, without disturbing any other ball excepting that which may be at the extremity of the row (484). Hence, in conformity with the premises, it seems to me that an acid can only reach the cathode, through an alkaline solution, by the endosmosis of the salt and its subsequent decomposition.

#### *Of the Electrotyping or Galvanotype Process.*

486. It has been represented, that during electrolysis, by a simultaneous exchange of partners throughout a row of atoms of water extending from one electrode to the other, an atom of oxygen may be liberated at the anode, and an atom of hydrogen at the cathode (358). Consistently, when a galvanic circuit comprises two electrolytes, separated by a porous diaphragm having a common anion, oxygen, for instance, but different cations, as, for example, hydrogen and copper, this metal may on one side of the diaphragm perform the office which hydrogen performs on the other side. Hence, while at the anode oxygen will still be evolved, a deposition of copper will, at the cathode, be substituted for the evolution of hydrogen. Of course, if instead of a solution of the oxide of copper, any other metallic oxide be substituted, the deposition of the metallic radical will take place of the evolution of hydrogen, unless the radical be one of those which decom-

the water on contact, at ordinary temperatures. If it be one of those, by the consequent decomposition of water, hydrogen will appear, as if water were the sole electrolyte. Analogous results will ensue, when any other simple electro-negative element is the common ingredient in electrolytes subjected to the galvanic current while separated by a membrane. Hence, the electrolyte process, which it is now the object to explain, only those metals can be employed, of which the deposition in the metallic state is practicable, in consequence of their not uniting with the oxygen of water.

487. It will be perceived, that there is a great analogy between the action of a simple battery for producing metallic depositions, and the constant battery of Professor Daniell. It is to the substitution of copper for hydrogen, as above mentioned, that the superiority of Daniell's battery is to be ascribed. By this change, cohesion between the cathion (360) and the surface of the conductor, acting as the copper plate in a galvanic triad (312, c.), is prevented; and this conductor, incessantly renovated superficially, presents always a bright metallic surface to the liquid.

488. After a constant battery, of the construction thus described, has been in operation for some time, on removing the coating of metallic copper from the surface of the copper plate, it is found to constitute a sheet of the deposited metal of greater or less thickness, and which is a perfect facsimile of the surface on which it has been formed, excepting that depressions and elevations are represented in the new plate, in the opposite kind of relief. Although these results could not have escaped the observation of experimenters with the constant battery, no useful consequences flowed from them until they were of a nature to afford, until the year 1838, when, through the ingenuity of Mr. Spencer, of Liverpool, and of Mr. Jacoby, of St. Petersburg, the new and important arts of electrotype and electro-gilding are invented.

489. If a piece of coin\* be made the negative surface of a simple gal-

Fig. 25.

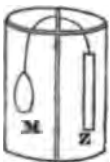
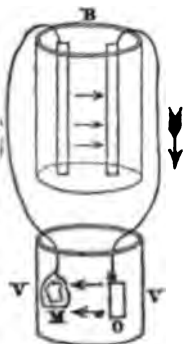


Fig. 26.



\* Figure 25 exemplifies a constant battery, arranged so as to serve for the electrotype process. A plate of zinc, Z, is suspended in diluted sulphuric acid, on one side of the porous diaphragm, a medal on the other, being severally attached to the ends of a copper wire.

Figure 26 will convey an idea of another mode in some respects preferable. The mould M is connected by means of a wire with the zinc of a Daniell's constant battery, a coil of copper is connected by the same means with the copper plate. Thus arranged, the coil and mould, or medal, acting as electrodes, are plunged into a concentrated solution of sulphate of copper acidulated by sulphuric acid, contained in a vessel without any porous partition, the coil being made to enter the solution first. It has been mentioned, that the true zinc end of a galvanic battery is negative. Of course the metal communicating with the zinc becomes the negative pole or cathode of a galvanic triad, (358) while the copper coil becomes the positive electrode. Under these circumstances the copper coil is oxidized and dissolved by the acid, while an equivalent portion of this metal is deposited on the mould.

The roll of sheet copper should be introduced first into the solution and must not touch the mould. Great precautions as to cleanliness must be employed in this, as well as in the former method of manipulating. When an arrangement of this description is set in action, for each equivalent of zinc, dissolved in the battery, an equivalent of copper is dissolved from the coil of sheet copper, and is pre-

vanic battery, by attaching it to a piece of zinc by means of a short and copper wire, the zinc being acted upon by a saline or acid solution upon one side of a porous diaphragm, while the coin is plunged into a solution of sulphate of copper upon the other side, the coin will be speedily covered with a light rose-coloured film of reduced copper, which by continuing the action for some hours, will become proportionably thicker, and may then be separated from the coin, by the application of a moderate heat. The metallic plate thus obtained, as already mentioned, will display a perfect reverse impression of the coin, and by making the copy thus procured, the conducting surface of a similar arrangement, a perfect impression in relief of the original will result. The conducting wire, and all those portions of the coin upon which copper is not to be deposited, must be coated, or varnished, with a non-conducting substance. The surface to be copied must be perfectly free from uncleanness, from grease especially. The coin should be immersed in the acid a little before the coin is plunged into the metallic solution, and the surface of the last should then be freed from air-bubbles by means of a feather or glass rod. The rapidity with which the deposition is effected, is greater in proportion, as the temperature of the solution is higher. But there is a certain degree of speed which should not be exceeded, as the texture of the metallic deposition is more compact when the process is slow.

490. A more expeditious method of producing the copy of a medal in relief, consists in first making a copy, by stamping clean sheet lead upon it, or pressing it upon fusible metal, while sufficiently soft: or taking an impression on plaster, the surface of the cast thus obtained, being made to conduct by means of a film of plumbago. The impressions thus procured may be substituted for the medal in the process above described.

491. These last mentioned expedients are peculiarly appropriate to

copied upon the surface of the mould connected with the zinc plate. By interposing between the zinc and copper of the generating cell a number of deposition-cells, similar to that already described, the mould of one, being connected with the copper roll of the next, and so on in the same order, any number of medals or medals may be copied at once, and at the expense of but a single equivalent of zinc.

The wires connected with the rolls of sheet copper should be varnished to prevent their being dissolved off the moulds, and the copper electrodes should be placed vertically and parallel to each other in the solution, and this last should be occasionally stirred with a glass rod to preserve a uniform degree of saturation throughout the mass of liquid.

Any conducting surface, negative to the zinc of the battery cell may be deposited upon in this apparatus. Hence, if surfaces of wax, wood, plaster, &c. be made to receive a thin coating of plumbago, by rubbing that material upon them with a brush, they may be made to receive a coating of metallic copper very nearly as uniform and as perfect as if they had been themselves of metal.

The accuracy with which the minutest elevations and depressions of a conducting surface may be copied, by means of the electrotype process, is so great, that the method has even been applied to the multiplication of Daguerreotype pictures, and the copies thus produced, are in every respect equal to the originals in perfect finish and minuteness of execution. They possess, besides, the advantage of being indestructible by friction and slight mechanical injuries. For this beautiful application of the discovery of Spencer and Jacobi, we are indebted to Mr. Endicott of New York.

The above described processes have not been confined to the production of electrotypes. They have been recently applied by M. Becquerel, in France, and to Jacobi, in Russia, to the separation of the precious metals from their ores, and agreeably to a statement made in some of the foreign papers, a mass of gold deposited in this manner, weighing half a pound, was presented a few months since to the King of Russia, by M. Jacobi.

copying engravings on copper, or wood, or in procuring stereotype plates from printing type set up so as to be ready for the press.

### *Of Electro-gilding and Electro-plating, &c.*

492. But a more generally useful application of the principle is the electro-gilding and plating, now in almost universal use. If any polished article of steel, copper, or brass, be connected with the zinc of the battery, and placed opposite a fine wire of gold or platinum, connected with the copper of the same, and if the two electrodes thus formed be plunged into a very dilute solution of chloride of gold, or chloride of silver, to which an equivalent of cyanide of potassium in solution has been added, a deposit of gold or silver will be effected, and the article will receive a fine coherent film of gold or silver, with a polish equal to that of the surface on which the deposit is made. Platinum may also be worked in the same way, though the operation is very far from being uniformly successful, and further experiments are wanting to render the process less precarious.

493. The process of electro-gilding has been employed in England, by Prof. Wheatston, and in Germany, by Prof. Steinheil, for the protection of the reflecting surfaces of the specula of reflecting telescopes, and specula of good instruments may be multiplied indefinitely, as well as very cheaply, by taking electrotype casts of their surfaces, and then gilding the reflecting surfaces of the copper specula thus obtained.

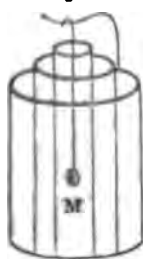
494. In depositing gold, silver and platina, by the electrotype process, it is necessary to employ currents of feeble intensity, and very weak metallic solutions, as the metals are very liable under the action of a very energetic current to be precipitated in a pulverulent form. By Mr. Davis, of Boston, the current of the magneto-electric machine was first employed for this purpose, and a patent has recently been obtained in England for the same process and manipulations.\*

495. Besides the applications of the electrotype which we have noticed, many others have been contemplated or employed, of which a due regard to brevity renders it inexpedient to give the details in this treatise.

### *Of Metallo-Chromes.†*

496. The name which forms the preceding head, has been given to certain beautiful colours, which may be produced upon a plate of highly polished steel by the electrolyzation of acetate of lead, while in contact with the steel surface. The following directions are given for the production of the phenomenon in question. Place the steel plate in a glass basin contain-

Fig. 27.



\* Fig. 27 represents an apparatus suitable either for the process of electro-silvering, or that of electro-gilding. It consists of a jar of glass, or glazed porcelain, within which is situated a jar of porous porcelain containing the metallic solution (493). The space between the two jars is occupied by a cylinder of zinc, and sulphuric acid very much diluted. A wire proceeds from the zinc cylinder, as represented in the engraving, for the purpose of supporting the article which is to receive the metallic coating. It is recommended to dip the article, which is the object of the process, in nitric acid, just before placing it in the circuit.

† The etymology of this name from *χρῶμα*, colour, in Greek, must be sufficiently obvious. As designating an iridescence produced by the peroxide of lead, it seems to me that a more appropriate appellation would be that of plumboxchromes.

ing a clear solution of the acetate of lead, and place over it a card, out of which some regular device has been cut. A small rim of wood should be placed over the card, and upon that a copper disk. On contact being made, from five to twenty degrees, in a circuit formed with two or three cells of a small constant battery, the steel plate being made negative, the copper disk positive, the deposit will be effected, and a series of exquisite colours will adorn the steel plate. These variegated tints are produced by the various tenuities of films of highly oxidized lead. Two sets of prismatic colours are produced, complimentary to each other, one by transmitted light, the other by that which is reflected from the steel. The colours are displayed in the greatest perfection, by placing the plate before a window, and inclining over it a sheet of white paper, at an angle of forty-five degrees.

### *Of the Galvanic Powers and Effects of Animal Organs.*

497. Under the preceding designation, it seems proper to treat of the galvanic apparatus and phenomena, which owe their existence to organic masses. It will be perceived by the student, who has given due attention to the preceding pages of this treatise, that this topic, has necessarily been in some degree anticipated. The references made to the convulsions produced in frogs, by an inherent electrical power, and to the shocks produced by electrical fishes, has already introduced organic galvanism to his notice.

498. Evidently of all the sources of the galvano-electric current, none are more interesting than the organs with which nature has furnished the torpedo, the gymnotus, and other electrical fishes.

499. *Of the Torpedo.*—Experimental evidence of the identity of the cause of the miraculous power of the torpedo, in giving shocks to other animals, seems first to have been satisfactorily obtained in the year 1792, through the exertions of Walsh, a sagacious electrician. In the following abstracts from a letter addressed to Dr. Franklin, this able observer gives an account of the facts which he had ascertained.

500. "It is with peculiar satisfaction, that I make to you my first communication, that the effect of the torpedo appears to be absolutely electrical. We have observed that the back and breast of the animal are in different electrical states, \* \* \* we have been enabled to direct his shocks through a circuit of four persons, all feeling them; likewise through a considerable extent of wire, held by two insulated persons, one touching the back, and the other the breast of the fish. These experiments have been varied in many ways, and repeated times without number, and they all determine the choice of conductors to be the same in the torpedo as in the Leyden phial."

501. Respecting the torpedo, I will quote a few paragraphs from a report made to the Academy of Sciences at Paris.

502. "The sensation which the torpedo causes when it is touched, has long ago attracted the attention of physicists and physiologists, on account of its analogy with that produced by an electrical battery, but it is only a few years since that it has been decidedly proved that both were owing to the same cause. Although all the principal circumstances of this phenomenon had previously been carefully studied, yet no one had succeeded in demonstrating its electrical origin from the want of suitable apparatus.

503. "John Davy made known, in a paper published in 1832, a great number of important data, such as the action of the discharge upon the magnetic needle, and chemical compounds; but the direction of the electrical current produced on this occasion was not well known until after the experiments made at Venice, 1835, by two of your members, and from which it resulted that the superior part of the electrical organ gives positive electricity, and the inferior part negative electricity. Matteucci has confirmed, with the galvanometer and frogs prepared after the method of Galvani, the observations which we had made respecting this point, as well as others also relating to the torpedo, for which we are indebted to various philosophers; at the same time he has demonstrated some new facts, of which the following is a short account.

504. "He commences by showing that when the torpedo lances its discharge, no change of volume is observed in its body. When the animal is possessed of great liveliness the sensation is felt at whatever point of the body it may be touched, but when its vitality is considerably diminished, the discharge is no longer felt, except by touching the electrical organs at two different points.

505. "Matteucci establishes the general laws of the distribution of electricity in this manner:—1. All the points of the dorsal part of the organ are positive relatively to the points of the ventral part; a fact already known. 2. The points of the organ on the dorsal surface placed above the nerves which enter it are positive in respect to the other points of the same dorsal surface. 3. The points of the organ situated on the ventral surface corresponding to the points which are positive on the dorsal surface, are negative in respect to the other points of the ventral surface. 4. The intensity of the current varies with the extent of the platina plates which terminate the galvanometer, and with which the two surfaces of the organ are touched.

506. "When the torpedo is very excitable the current may be compared to that of a pile consisting of a great number of pairs charged with a good conducting active liquid; whilst, on the other hand, when its liveliness is weak, the electric current resembles that of a pile composed of a small number of elements.

507. "The spark which accompanies the discharge in the electrical fishes was remarked for the first time by Walach in the *Gymnotis*; many vain efforts have been made since to reproduce it; MM. Matteucci and Linari have succeeded in obtaining it in every case from the torpedo; both these philosophers claim the priority of the observation.

508. "Matteucci has since succeeded in obtaining the spark by placing

the torpedo upon an isolated plate of metal, and placing another plate of metal above it, then fixing to each of them a gold leaf separated the one from the other by the distance of half a millimetre. By slightly moving the upper metallic plate the animal became irritated, and at the same moment the two leaves approached one another and the report of the spark was instantly heard.

509. "M. Matteucci having entirely separated from a great torpedo one of the electrical organs, without detaching the epidermis, one of the plates of the galvanometer was inserted in the organ near the outward edge, the other plate was put in communication with one of the four nerves; the needle deviated four degrees in the common direction of the discharge of the torpedo; on tying the nerves there was no longer any deviation. The result appears to us very remarkable.

510. "The above observations, which we have not been able to confirm from the want of torpedoes, go to prove, 1st, that the electricity which produces the discharge proceeds from the last lobe of the brain, and is transmitted by the nerves to the organ; 2, that the discharge ceasing under the influence of the electric current, when the nerves are tied, must, in order to be transmitted, find in the nerve a particular molecular disposition; a conclusion to which the electro-physiological phenomena of the frog equally lead, as one of us (M. Becquerel) has indicated in various places in his treatise on electricity.

511. "Since the ever memorable epoch when Galvani demonstrated that the contact of two different metals in communication with the muscles and nerves of a frog sufficed to make it contract, the experiments have been varied infinitely in the hope to discover in this phenomenon the cause which constitutes life in animated bodies. The most remarkable fact, for which we are also indebted to Galvani, is that which relates to the contractions produced by the simple contact of the muscles and nerves without the intermediary of metallic armatures. It is now nearly demonstrated that this action does not proceed from a chemical action, but from the inherent current of the frog, which has been indicated with so much sagacity by M. Nobili."

512. The opinion and facts with which these quotations tend to make the reader acquainted, seem to me to prove that if Volta was right in conceiving the powers of his pile as independent of vital action, still Galvani was justified in supposing that animal organization could give rise to analogous results.

513. *Of the Gymnotus Electricus.*—According to Humboldt, the gymnotus abounds in the small rivers which flow into the Orinoco. It employs its electrical powers as other animals do their horns, teeth, or fangs, to secure its prey or repel aggression. Hence, horses or mules are attacked by them, when forced reluctantly to enter the streams in which they reside; and while, on the one hand, the quadrupeds suffer severely, from the shocks which they receive



their assailants are so exhausted, as to be unable either to give further shocks, or to escape from seizure.

514. The gymnotus is sometimes five feet in length. One of the length of forty inches was lately conveyed to England, and put at the disposal of Faraday, who has given a most valuable account of the various phenomena noticed by himself, and other intelligent observers.

515. The shock was most powerful when the hands were made, the one to touch the animal near the head, the other near the tail, and was less severe in proportion as the distance between the hands was less. When the points of contact were in a line at right angles to the spine, little sensation could be produced.

516. The farther the hands were from the fish, while the line extending from one to the other was parallel to the spine, the less was the sensation experienced, and the diminution became greater in proportion, as the line joining the points of immersion deviated from parallelism with the spine.

517. Conductors of an ingenious construction, being applied to the anterior and posterior parts of the gymnotus, Faraday gives an account of the results in the following words:—

518. "A galvanometer was readily affected. It was not particularly delicate; for zinc and platina plates on the upper and lower surface of the tongue did not cause a permanent deflection of more than  $25^{\circ}$ ; yet when the fish gave a powerful discharge the deflection was as much as  $30^{\circ}$ , and in one case even  $40^{\circ}$ . The deflection was constantly in a given direction, the electric current being always from the anterior parts of the animal through the galvanometer wire to the posterior parts. The former were therefore for the time externally positive, and the latter negative.

519. "*Making a magnet.* When a little helix containing twenty-two feet of silken wire wound on a quill was put into the circuit, and an annealed steel needle placed in the helix, the needle became a magnet, and the direction of its polarity in every case indicated a current from the anterior to the posterior parts of the gymnotus through the conductors used.

520. "*Chemical decomposition.* Polar decomposition of a solution of iodide of potassium was easily obtained. Three or four folds of paper moistened in the solution were placed between a platina plate and the end of a wire also of platina, these being respectively connected with the two middle conductors. Whenever the wire was in conjunction with the conductor at the fore part of the gymnotus, iodine appeared at its extremity; but when connected with the other conductor none was evolved at the place in the paper where it before appeared. So that here again the direction of the current proved to be the same as that given by the former tests.

521. "By this test I compared the middle sections before and behind it, and found that the middle was negative to the anterior parts, was, on the contrary, positive near the tail. So that within certain limits internally at the time of the shock appears negative to other parts anterior to it, and

522. "*Evolution of heat.*" Using a long to Mr. Gassiot, we thought we were when the deflection of the galvanometer was a function of temperature. I was not observing of those who at first believed they saw the

523. "*Spark.*" The electric spark is taken from a galvano-electric coil, with a core of soft iron, and is applied to the end of one of the saddle collectors, by means of a file; another file was made fast to the end of the other, and the person then rubbed the point of one of the files against the end of the other, whilst another person put the collectors in motion. This will excite it to action. By the friction of the files, the sparks are taken very frequently; and the object was to show that the electricity was to be taken through the wire and helix, and by means of the files to make the electricity sensible as a spark.

524. "The spark was obtained four times. The first sent saw it. That it was not due to the friction was shown by its not occurring when the file was used. Evidently of the animal. Since then I have used a revolving steel plate, cut file fashion on iron, copper and silver, with all of which it has occurred."

525. It has been shown there may increase voltaic power, or quantity, the other, that of increasing the latter, the conducting power. In the case of an animal created for this purpose, of course, to secure to these elements the weapon with which they are endued, an enormous quantity of the material is at their disposal.

526. The shock from the galvanic observations were made, was, as to that of a large Leyden battery of intensity; or to a voltaic series the circuit should be completed

527. He conceived it to cor

\* "In more recent experiments of the same

† "At a later meeting, at which attempts gold leaves, the spark was obtained directly coil being removed, and only short wires (by

city equivalent to a high charge from a coated surface of 3500 square inches.

528. The gymnotus gives sometimes two, and at other times, even three successive shocks; as had been previously noticed in the case of the torpedo, by various distinguished observers.

529. At the moment when the fish wills the shock, of two parts of the body parallel to the spine, that which is nearer the head will be positive, the other negative.

530. The fish has four electric organs, which, it is conceived by Faraday, it may have the power to throw into action separately, or together, and so as, to a certain extent, to direct the shock at the moment of the discharge. But it is not inferred that the direction of the current can be controlled after it has entered the liquid or other surrounding bodies.

531. I saw the gymnotus with which these experiments were made in 1841, and received a shock from it. I was moreover gratified at seeing what I had not been led to expect, the deflagration of a thin metallic leaf by subjection to a circuit formed with the aid of the animal.

532. The gymnotus can stun or kill fish in various positions of its body, but in killing a small fish, thrown into the tub, was found to coil i'self so as to make the fish occupy the situation of a diameter to the resulting coil. In an instant the fish was struck dead and motionless, and turning on its side, was soon bolted by its hungry assailant.

533. "Living (says Faraday) in the midst of such a good conductor as water, the first thoughts are thoughts of surprise that it can sensibly electrify any thing; but a little consideration soon makes one conscious of many points of great beauty, illustrating the wisdom of the whole arrangement. Thus the very conducting power which the water has; that which it gives to the moistened skin of the fish or animal to be struck; the extent of surface by which the fish and the water conducting the charge to it are in contact; all conduce to favour and increase the shock upon the doomed animal, and are in the most perfect contrast with the inefficient state of things which would exist if the gymnotus and the fish were surrounded by air; and at the same time that the power is one of low intensity, so that a dry skin wards it off, though a moist one conducts it; so is it one of great quantity, that though the surrounding water does conduct away much, enough to produce a full effect may take its course through the body of the fish that is to be caught for food, or the enemy that is to be conquered.

534. "Another remarkable result of the relation of the gymnotus and its prey to the medium around them is, that the larger the fish to be killed or

stunned, the greater will be the shock to which it is subject, though the gymnotus may exert only an equal power; for the large fish has passing through its body those currents of electricity, which, in the case of a smaller one, would have been conveyed harmless by the water at its sides.

535. "The gymnotus appears to be sensible when he has shocked an animal, being made conscious of it, probably, by the *mechanical impulse* he receives, caused by the spasms into which it is thrown. When I touched him with my hands, he gave me shock after shock; but when I touched him with glass rods, or the insulated conductors, he gave one or two shocks, felt by others having their hands in at a distance, but then ceased to exert the influence, as if made aware it had not the desired effect. Again, when he has been touched with the conductors several times, for experiments on the galvanometer or other apparatus, and appears to be languid or indifferent, and not willing to give shocks, yet being touched by the hands, they, by convulsive motion, have informed him that a sensitive thing was present, and he has quickly shown his power and his willingness to astonish the experimenter.

536. "It has been remarked by Geoffroy St. Hilaire, that the electric organs of the torpedo, gymnotus, and similar fishes, cannot be considered as essentially connected with those which are of high and direct importance to the life of the animal, but to belong rather to the common teguments; and it has also been found that such torpedoes as have been deprived of the use of their peculiar organs, have continued the functions of life quite as well as those in which they were allowed to remain. These, with other considerations, lead me to look at these parts with a hope that they may upon close investigation prove to be a species of natural apparatus, by means of which we may apply the principles of *action and reaction* in the investigation of the nature of the *nervous influence*."

537. I cannot perceive, with Faraday, that the facts above mentioned, as stated by him, are *all* consistent with the idea of the powers of the gymnotus, being due to a great quantity of statical electricity of low intensity.

538. The fact which appears to me inexplicable, upon this view of the subject is, that a shock should be received by a person having only one hand in the water containing the fish.

539. Agreeably to universal experience, no shock can be received by any person who is not within the electrical circuit through which the discharge is made; or of some other induced circuit in the vicinity. But within what circuit can a single hand be brought, unless the body and legs of the person to whom it belongs, the floor on which he stands, and the tub containing the gymnotus, be made to form a conducting communication between the organic electrodes of that animal. But if the electricity discharged through these electrodes be of an intensity too low for

them to discharge themselves through the water, a fortiori, must be too low to make its way by means of the floor of which the conducting power must be vastly inferior to that of water.

540. I regret that it was not ascertained whether this result could not have been prevented by placing the tub upon glass legs, as dry as possible.

541. I doubt if a voltaic series of 100 large pairs, placed in water as the fish was, would cause shocks to a person on immersing only one hand.

542. A battery of 100 pairs, when out of water, will not, agreeably to my experience, give a shock to one hand. Of course, it could not do more when submerged in that liquid.

543. It is difficult to reconcile this fact with the idea, that the powers of the gymnotus are those of a large Leyden battery lowly charged, unless it be supposed that the animal is enabled to project the electric fluid in obedience to its will, as the porcupine has been supposed to shoot forth his quills.

544. The anatomical researches of Hunter, and other anatomists, have been considered as demonstrating, that the electrical organs of the torpedo, bear a very striking resemblance to a galvanic series in the columnar forms of the original pile of Volta. They have been alleged to consist of hexagonal columns, amounting in one instance, to one thousand one hundred and sixty-two, arranged like the cells of a honey comb, each column consisting of a pile of flat disks separated from each other by cellular tissue. The organ is abundantly furnished with nerves. Nevertheless, little satisfaction seems to have been afforded by the investigation of anatomists respecting the mechanism, by which nature has endowed this animal and other electrical fishes with their peculiar powers.

545. Both Matteucci and Schoenbien concur in considering, that neither dissections, observation, nor experimental inquiry, have thus far afforded any competent explanation of the apparatus by which the powers of the torpedo or gymnotus are imparted and made obedient to animal will. By the former it is alleged, "that it is impossible to find the least analogy between piles, secondary coils, batteries, and the electric organ of the torpedo:"

by the latter, after a careful repetition of the experiment of Faraday, with the same gymnotus, it is stated as the result of his mature consideration, "that the true cause of the phenomena is still completely obscure, and must not be sought for in the physical or chemical constitution, or in a fixed organization of certain parts of the animal; that there exists, without our being able at present to determine how, an intimate connexion between the actions dependent on the will of the fish, and the physical phenomena which these vital actions produce."

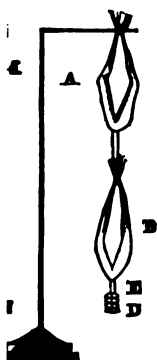
*Of the Observations of Nobili, Matteucci, and Others.*

546. It has been mentioned that Galvani considered that the current produced in frogs by contact with metals, or the proximity of the disk from the conductor of an electrical machine, as more or less dependent on a diversity of electrical excitement in the different animal organs.

547. That Volta having subsequently discovered his pile to be more of producing effects altogether independent of the animal, similar in character and vastly more powerful than those noticed by Galvani, the eminent philosopher was led into an error, which was generally adopted, supposing that the organs of a frog, when convulsed by an electrical charge, are in all cases the medium, not the source of the current. Y recent observations of Nobili and Matteucci, have shown that although impressions of Galvani may not have been warranted by any of his experiments, they are fully justified by those which have been recently made.

548. From the experiments of Matteucci, it appears, that in frogs there is a current, peculiar to them, proceeding from the feet towards the head. This can be made sensible either by the deviation caused in the needle of a very delicate Sweiger's galvanometer of 2500 circumvolutions, or by the contractions produced in the leg of another frog, of which the dorsal spinal nerve is made the medium of discharge. I shall call a frog's leg and nerve thus prepared, a galvanoscopic frog limb. To produce the current in question, only the leg of the animal is necessary; although, in several experiments, the leg, thigh, denuded nerve, and a portion of the spine, are mentioned as being employed. The author in one of his experiments, uses the following language: "*Each member of a frog, comprising the leg, thigh, spinal nerve, and a small portion of the spine, constitutes a complete electromotor.*" Yet it fully appears from his subsequent narrative, that the thigh, nerve, and spine, contribute nothing to the motive energy. The nerve, from its low conducting power, rather diminishes than increases the intensity of the discharge. It follows from the statement, above made, should have been reserved for the leg of the frog; which, agreeably to the author's observations, is really an electromotor as much as any galvanic triad (312). It does not appear to be determined, what portions of the leg perform respectively the parts of copper and zinc: the sanguineous liquid, retained in the pores of the flesh, seems to act as the electrolyte.

Fig. 28.



549. Nobili had found, that by disposing a number of frogs in such order as to resemble a voltaic series, an increase of power in the resulting electrical current would ensue. To construct such a series, it is sufficient that the frogs, duly prepared, be supported by one or more non-conductors, so that their dissimilar extremities may be in contact, or communicate through weak brine, forming thus a species of *couronne des tasses*. The adjoining figure illustrates one convenient mode among others, by which the frog limbs may be connected, so as to be in voltaic order. Of course the series might consist of several similarly associated. MN is a glass rod, by which the frog's limbs, A, and those at B, are supported and insulated. According to Sturgeon, when the spine, D, of B, is, by means of another glass rod, brought into contact with the feet of A, convulsions are produced. Moreover, it will be

seen, that agreeably to the experiments of Nobili, and those of Matteucci, when a conducting communication is made between the extremities of such an organic series, through the coil of a galvanometer of 2500 circumvolutions, deviations are produced, which are, as far as tried, greater in proportion to the number of the series.

550. At first the frogs thus employed were prepared as above described, as to consist of the legs, thighs, and a bit of spine, but Matteucci discovered that, as naturally associated, one limb operated in some degree as a charger to the other, so that on the removal of one, the other became more efficient. It has been mentioned that the thigh and nerve added nothing to the electromotive power. Accordingly it was found that a battery might be made of legs only, the feet belonging to one leg touching the nuded muscular extremity of another, so that the dissimilar parts of the whole number were in contact in voltaic order (362).

551. Of the voltaic series thus formed, the effects upon the needle of the galvanometer increased within certain limits with the number, so that when one element could produce a deviation of only four or five degrees, the series would produce fifteen to twenty degrees.\* These deviations were of a nature to show that the current sets invariably from the feet towards the rest of the limb. The current, thus described, is designated by Matteucci the current proper to the frog. He has not been enabled to detect anything analogous to this current in any other animals of a neighbouring order, such as lizards, tortoises, or eels.

552. Nevertheless, agreeably to the same authority, currents may be shown to take place from the internal to the external portions of the muscles of both warm and cold blooded animals, by which, deviations in the galvanometrical needle and contractions in a galvanoscopic frog's leg may be produced, as striking as those resulting from the current proper to frogs.

553. Sections of thighs of frogs, of the bodies of eels, or of the thighs of rabbits or pigeons, being arranged in a series of eight or ten on a varnished plank, so that the internal surface of one should touch the external surface

\* The deviations of the needle of a galvanometer are estimated by a semi-circle, graduated to ninety degrees on each side of the point at which it rests when undisturbed.

the external, the skin being removed, a current is c parts to the outer.

556. That this current varies as to intensity : whose muscles are employed.

557. That by disposing duly made sections of described, in a series, voltaically, the intensity of t tion to the number of the sections so associated.

558. The author adverts to a fact which he had when water and blood communicate through a liqu is induced from the latter to the former. Foresee presented as accounting for the current from the in mal muscle, he points out that a current, resulting in the muscle and the water used as a conductor, its effect on the needle to that observed, which is o the direction being from the water towards the se a conclusive answer to the objection thus founded, the galvanometer were due to the electromotive water, arranging the sections, so as to form a volta augmented the intensity as it was actually ascertain

559. Further, it is alleged that the current dete between water and blood, endures without diminut that which takes place in the muscles of recently sient, and ceases sooner in proportion as the anima

560. Contractions were produced in the leg o when the nerve was made to complete the poles of of moistened paper. Even when the paper was se that the galvanometrical needle was not affected by platina blades in contact with the paper at different communications between the paper and frog, cor longer the strip of paper employed for a part of th number of the sections requisite to produce the con

*Of Galvano-Electrical Currents in Lit*



562. An experiment is described, in which several live frogs were subjected to a process, which may be literally considered as excruciating, by filing their feet against a varnished plank, removing their legs, skinning their thighs, and in cutting in half each alternate thigh; then the uncut thigh of the first, and the raw surface of the remaining half of the next thigh, were brought into contact in voltaic succession. By these, a series of four elements gave a current of twelve degrees, always from the interior to the surface.

563. The galvanometrical deviations caused by a current obtained from a live sheep, or rabbit, by the means above described (560), was more than six times greater than those obtained from a frog in like manner.

564. The potency of muscular batteries, in which the size of each element in one, was uniformly double or triple that of those in the other, was found nearly the same; since, when they were so arranged as that the one counteracted the other, there was scarcely any current produced by the excess of power in the larger element. When, of two batteries of frog thighs, of the same size and number, the nerves were removed only from one, no diversity of power was found to ensue: so that the muscular current depends neither as to quantity, nor as to intensity, on the integrity of the nervous system of motion and sensorial power. Two batteries of ten elements each, being constructed, the one of the thighs of frogs, of which the spinal marrow had been destroyed by a hot iron, and their lower limbs thus paralyzed, the other differing only in being made from animals of the same kind, in which the spine had sustained no injury, it was found that where the two batteries were made to act in opposition in the same circuit completed by the galvanometer, the deviations of the needle in the direction of the former, was from sixteen to eighteen degrees. In fact, this battery gave separately, from fifty to fifty-five, while the other gave only from forty to forty-five degrees.

565. This is considered as confirming the inference already made, that the integrity of the motive and sensorial nervous system, has no bearing on the intensity or the direction of galvano-muscular currents. Whether or not, the frogs from which batteries were constructed, had been rendered drowsy by opium, nux vomica, or other narcotic poisons, made no difference in the currents which they gave; excepting in one instance, in which it seemed as if a feeble dose augmented the power of the current. Moreover, it is not to be inferred, that the capacity to produce a current, is not enfeebled or destroyed, when narcotics have been used to an extent to produce death. Frogs, thus poisoned, are as unsuitable for a battery, as those which have been dead for a much longer time, after being killed and prepared in the usual manner. In operating with the muscles of a pigeon, which had been more or less poisoned, similar results were attained. Contrasting the galvano-electric power of equal series of the muscles of frogs or pigeons killed by immersion in carbonic acid, cyanhydric acid, or arsenuretted hydrogen, and of such as were killed as usual, no superiority was found in any case, excepting that a little superiority appeared in the muscles of those which had been poisoned. Yet, in the case of muscles from frogs, or pigeons, killed by sulphuretted hydrogen, a great loss of power was discovered, as contrasted with the muscles of animals prepared in the ordinary way; since, when by a similar series of the latter, scarcely any deviation could be obtained, by the former fifteen degrees were effected.

The following is the author's summary of his inferences.

566. 1st. The intensity of the galvano-muscular current, as measured

by deviations of the galvanometrical needle, varies in cold blooded animals proportionally to the temperature of the medium in which they have lived for some time previously to the experiments.

567. The durability of the current, is less in proportion, as the animal is more elevated in the scale of beings.

568. The intensity of the current varies as the animal has been better or worse fed, and is invigorated by inflammation, or sanguineous congestion resulting from a wound.

569. It is independent of the integrity of the nervous system, as may be seen in the sensorial and motive power.

570. Narcotic poisons have scarcely any influence on this current as respects intensity, and as to its direction they have none.

571. Among gaseous poisons, sulphuretted hydrogen, is to a certain extent, productive of an enfeebling influence, while cyanhydric acid, and seniuiretted hydrogen, if productive of any change, strengthen it a little.

572. The direction and the strength of the galvano-muscular current are altogether independent of any assistance from the nerves, which are only as imperfect conductors, representing and transmitting the electric excitement of the muscle with which they are associated.

573. Messrs. Pacinotti and Puccinotti, of Pisa, in a great many experiments, in which one of the blades of a galvanometer was plunged into the leg, the other into the brain, obtained deviations of the needle, which at the same time sufficiently striking, and of a nature to demonstrate the existence of a current flowing from the brain towards the muscular part of the animal fabric.

574. Alluding to these results, Matteucci adverts to the difficulty of avoiding erroneous results. He suggests that the action of the blood flowing copiously from the wound in the brain as usually made, is aided by its reaction with the terminating blades of the galvanometer, to produce deviations, especially as, in order not to diminish the vitality of the animal, it had been preferred to perforate the head the last. Merely the friction resulting from moving the blades is sufficient to increase the deviations. Having himself taken various precautions, the deviation on first immersion was always such as to comport with a current in the direction from the brain towards the feet, as observed by the electricians above named. Matteucci's statement, that deviation varied from eight to ten degrees as the current did not persist in its direction after the first plunge, and very much enfeebled after the third immersion, and was very often reversed, it does not seem that much reliance is to be placed on the exactness and direction of the current in question.

575. Assuming, however, that there is a current from the brain to the lower parts of the body or limbs, our author conceives, that it is a consequence of the nervous system acting as a conductor to the muscular masses into which the nerves ramify. Yet, he admits, that this idea is altogether compatible with the fact of the production of a current of electricity either by a contact with the interior of any of the muscles, or with the muscular surface; and, further investigation is requisite for the elucidation of this subject.

576. The author concludes with this observation. Perhaps the nervous system may exercise on the galvano-animal current an indirect influence arising from its participation in the process of muscular nutrition, which is not, however, possible to prove by direct experiments.

# EXHIBITION OF VOLTAIC SERIES OF VARIOUS CONSTRUCTIONS.

577. Voltaic Pile, as originally constructed, exemplified—also the Couronne des Tasses.

578. Apparatus, employed by Sir Humphrey Davy, exemplified by two porcelain troughs, in each of which are suspended ten pairs, consisting severally of a zinc and a copper plate.

579. Apparatus exhibited, in which the cells are made by partitions of glass, and the galvanic pairs, instead of being attached to beams in order to be lifted out of the acid, are kept permanently in their cells; the acid being removed by a partial revolution of the trough upon pivots, when the action is to be suspended.

580. Construction of Cruikshank pairs and trough illustrated.

581. Galvanic deflagrators exhibited of various dimensions and numerical extension, combining the advantages of the Cruikshank trough with those of the deflagrator.

582. Effect of the circuit upon the animal frame.

583. Iodine evolved and made evident by starch.

584. Water decomposed, and recomposed.

585. Various apparatus for different amalgams produced.

586. Deflagration, fusion, and volatilization of charcoal, metals, anthracite, and plumbago, exhibited. Likewise of various metallic wires, of tin-foil, tinsel, and mercury. Fusion and incorporation of iron and platina, under water. Hydrate of potash deflagrated upon charcoal, and upon a piece of silver coin.

587. Fusion of platina, on contact with chloride of calcium and other solutions in the voltaic circuit.

588. De Luc's columnar apparatus exhibited and explained.

## *Exhibition of*

Grove's gas battery.

Daniell's original constant battery.

Improved constant battery.

Grove's sustaining battery.

Apparatus and processes for electro-typing, also for electro-gilding and silvering, &c., and metallo chromes.

### *Of a Process for Rock-blasting.*

589. I have already adverted to the efficacious and perfectly safe process, for rock-blasting and blowing up wrecks of vessels, fortifications, &c., with which I was privileged, in 1831, to ignite twelve charges of gunpowder at the distance of one hundred and fifty feet (447). Hoping that it will serve the cause of humanity to make this process better known, I subjoin the original account of it as published in the Journal of the Franklin Institute in 1833 Vol. XX. page 221.

*Description of a Process and an Apparatus for Blasting Rocks, by means of Galvanic Ignition. Communicated by Robert Hare, M.D., Professor of Chemistry in the University of Pennsylvania.*

590. I have observed various accounts in the newspapers of workmen killed dreadfully lacerated, by the blasting of rocks.

591. I have ascertained that by a new application of galvanism, rocks may be riven with less danger than that which attends the firing of a pistol. I was induced to attempt this improvement in consequence of an application by a patentee (Moses Shaw,) for assistance in perfecting his patented mode of blasting rocks, by electrical discharge from a Leyden jar.

592. In a letter dated June 1st, 1831, he says, "I have been engaged in blasting rocks by means of a fulminating powder, introduced into several cavities, and ignited in all of them simultaneously, by a spark from an electrical machine. By this means masses of a much larger size, and of a much more suitable shape for the object in view, may be procured, than by the old plan. I have, however, been deterred by my inability to succeed in this method of blasting, during a great part of the time, when, in consequence of the unfavourable state of the weather, the ignition could not be effected by electricity in any mode which I have devised, or which has been suggested by others, although I have consulted all the best informed professors to whom I have had access."

593. It occurred to me, as soon as this statement was made by Mr. Shaw, that ignition of gunpowder, for the purposes he had in view, might be effected by a galvanic discharge from a deflagrator, or calorimotor, in a mode which I have long employed in my eudiometrical experiments to ignite explosive gaseous mixtures. This process is free from the uncertainty, which is always more or less attendant upon the employment of mechanical electricity, for similar purposes.

594. The expectation thus arising, has since been fully verified. I have ignited as many as twelve charges of gunpowder at the distance of one hundred and fifty feet, from the galvanic machine employed. This distance is much greater than necessary to the safety of the operator, as the deflagrator may be shielded so as not to be injured by the explosion, and by means of levers and pulleys it may be made to act at any distance which may be preferred. There is no limit to the number of charges which may be thus ignited, excepting those assigned, by economy, to the apparatus employed.

595. These remarks have reference to the principal and highly important object of Mr. Shaw's project, which is to ignite at once a great number of charges, in as many perforations so drilled in a rock, as to cooperate simultaneously in the same place. By these means it is conceived that the stone may be separated into large prisms or tabular masses, instead of being reduced to irregular fragments of an inferior quality. The object to which I propose now to call attention more particularly, is a mode

on of the common process of blasting by one charge, which renders that process perfectly safe.

596. This part of the subject I shall introduce by premising, that almost all the accidents which have taken place in blasting rocks, have occurred in one of the three following modes:—

1st. The explosion has taken place prematurely, before the operator has had time to retire.

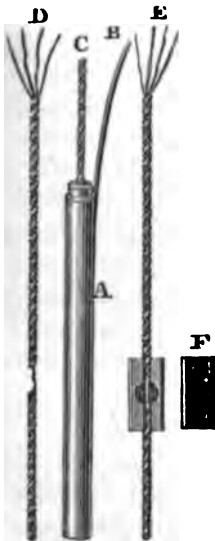
2d. A premature explosion has ensued from a spark produced by the collision arising from ramming into the perforation, containing the powder, the brickdust, or sand, or other matter, employed to close it.

3d. The fire not reaching the charge after the expiration of a period unusually long, and the operator returning to ascertain the cause of the supposed failure, an explosion ensues when he is so near as to suffer by it, as in the instance near Norristown, published some years ago.

The means of communicating ignition, to which I have resorted, are as follows:—

597. Three iron wires, of which one is of the smallest size used for wire gauze, the others of the size (No. 24,) used by bottlers, are firmly twisted together. This is best accomplished by attaching them to the centre of the mandril of a lathe, which is made to revolve while the other ends of the wires are held by a vice, so as to keep them in a proper state of tension. After being thus twisted, a small portion is unwisted, so as to get at and divide the larger wires by means of a pair of nippers. In this way the smaller wire is rendered the sole mean of metallic connexion between the larger ones. These are tied in a saw kerf, so made in a small piece of dogwood as to secure them from working, which, if permitted, would cause the smaller wire to break apart. At one end, the twist formed of the wires is soldered to the bottom of a tin tube of a size to fill the perforation in the rock to such a height as may be deemed proper. This tube being supplied with gunpowder, the orifice is closed with a cork, perforated so that the twisted wire may pass out through it without touching the tube at any point above that where the finer portion alone intervenes. To the outside of the tube, a copper wire, about No. 16, is soldered, long enough to extend to a stout copper wire proceeding from one of the poles of a galvanic deflagrator or calorimotor. The wire passing through the cork from the inside

Fig. 29.



of the tube, is in like manner made to communicate with the other pole. The connexions between the wires and the poles, should be made by means of soft solder, previously to which we must imagine that the tube has been introduced into a perforation made for its reception in a rock to be blasted. The tin tube may be secured within the rock by the usual method of ramming in brickdust or sand, by means of a plug, having holes for the protection of the wires of communication already described.\*

598. The apparatus being thus prepared, by a galvanic discharge, produced by the movement of a lever through the quarter part of a circle, the finer wire is ignited, in the place where it intervenes solely in the circuit, so as to set fire to the surrounding gunpowder.

599. As the enclosure of the gunpowder in the tube, must render it impossible that it should be affected by a spark elicited by ramming, as no means of ignition can have access to the charge besides the galvanic discharge; and as this can only occur by design, without an intention to commit murder or suicide, or by unpardonable neglect, it is inconceivable that an explosion can take place in this method of blasting, when any person is so situated as to suffer by it.

600. It must be obvious that in all cases of blasting under water, the plan of a tin tube, and ignition by a galvanic circuit, must be very eligible.

601. At A is represented a cylinder or tube of tinned iron, replete with gunpowder. At C, the twisted wires are represented as they protrude from the cylinder through a cork, by which the latter is closed at the upper end.

\* It has occurred to me that plaster of Paris might be used advantageously, as it would require no ramming, and might set with sufficient firmness.

The other ends of the wires are soldered to the metallic disk which forms the bottom of the cylinder. D represents the twisted wires as they appear when all the larger ones are cut, the smaller wire still uniting them. F represents the piece of dogwood, duly prepared; and E the wires as when supported by the wood. The reader is only to imagine the hole in the wood to be supplied with the fulminating composition, and covered by a fillet of paper or cloth, glued or pasted around the wood, in order to complete his conception of the wires as finally accoutred and situated within the cylinder A.

602. Besides affording support to the larger wires, and thus protecting the smaller wire uniting them from fracture, the piece of dogwood which has been described, by means of the small hole represented in it, serves to hold, and to preserve in contact with the little wire, some fulminating powder. This not only facilitates the precipient ignition of the contents of the cylinder, but must make it extend more rapidly throughout the mass, and must, of course, cause it to be more powerful. Metallic arsenic, and chlorate of potash finely powdered and mingled, make an excellent explosive powder for this purpose; being more ready to explode from heat, and less so from other causes, than fulminating silver or mercury. Sulphur may be used in lieu of arsenic. Yet the use of these is not necessary, as the gunpowder will take fire directly from the wire, at least as effectually as in the usual mode. The mixture of gum phosphorus, sulphur and chlorate of potash used for matches, will answer, no doubt, in lieu of the preparation mentioned.

## ELECTRO-MAGNETISM.

720. The science of Electro-magnetism may be said to consist of a knowledge of a series of facts ascertained respecting the influence of active electric circuits with each other, or with bodies which may have been magnetized, or which are susceptible of being rendered magnetic. To describe and illustrate experimentally, some of the most striking among the facts, to which allusion is thus made; giving also such theoretic elucidation as the present state of science will afford, is all that the limits prescribed to this treatise will permit.

721. The science of Electro-magnetism may be considered as comprising the following branches, each producing, as its appropriate fruit, phenomena, which are not only highly wonderful and interesting, but likewise of great practical importance.

### SYNOPSIS.

*Reciprocal reaction of Magnets.*

*Reaction between Magnets and Electrical Currents.*

*Attraction and Repulsion between Electrical Currents and the Movements thence arising.*

*Induction of Currents by Electrical Currents, or Electrodynamic Induction.*

*Induction of Magnetism by Electric Currents, or Electromagnetic Induction.*

*Induction of Electric Currents by Magnetism, or Magneto-electric Induction.*

722. It had long been observed, that there were striking analogies, as well as discordancies, between the characteristics of electricity and magnetism. The similar poles of magnets, freely suspended,\* were observed to recede from each other, and dissimilar poles to approach each

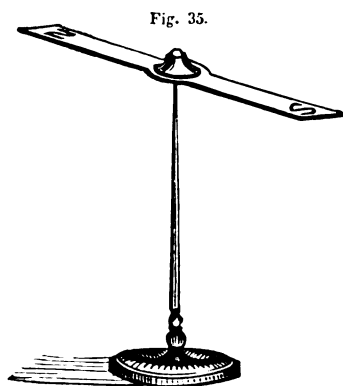
\* Allusion is here made to what is called usually a magnetic needle, as represented in figure (35).

other, in a mode quite analogous to the separation and approximation, under like circumstances, of substances similarly or dissimilarly electrified.

723. It had also been observed, that iron, in the vicinity of lightning rods, or otherwise indirectly affected by lightning, had in some instances been rendered magnetic.

724. So far then, the existence of an analogy, or association, between electrical and magnetic phenomena was demonstrable; but, the magnetic repulsions and attractions took place under circumstances extremely favourable to the existence of the opposite electrical effects. The magnetic needle being a perfect conductor, there could of course be no permanent existence of opposite electrical excitement at the extremities. Moreover, the north pole of a magnet was more susceptible of being attracted by electrified bodies, than any other metallic wire, suspended; nor did either of the electricities affect the pole more than the other. The poles of the voltaic circuit were found to be perfectly indifferent to the magnet, when it was presented to them, during the interruption of the circuit, which was deemed necessary for the production of electrical excitement.

725. The contact of another magnetizable body, such as iron for instance, was found to strengthen and produce the opposite magnetic excitement, while a similar contact would be destructive of the opposite electrical excitement.



726. Under these circumstances, then, it never occurred to any one, that the magnetic poles could be influenced by electricity, whether galvanic or mechanical, till Professor Oersted, in the winter of 1820, ascertained the existence of a reciprocal influence, between the magnetic needle, and the wire connecting the poles of a galvanic apparatus. In consequence of this influence, in

addition to terrestrial gravitation and magnetism, the needle, when freely suspended, was found to assume invari-

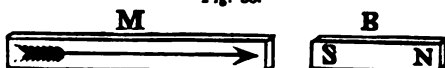


position at right angles to the direction of the current, or more precisely, that of a tangent to a circle, concentric with, and at right angles to, the axis of the wire through which the current flows (742). Reference has been made to this wonderful reciprocal influence and the admirable galvanometrical invention to which it gave rise (306). It will be treated of more particularly under the appropriate head: *Reaction between Magnets and Currents* (731, &c.).

### Of Magnetic Induction.

727. Magnetism has some analogy to statical electricity in the phenomena of *induction*, but utterly differs from it as respects *conduction*.

Fig. 36.



728. Thus the bar of iron B, figure 36, becomes magnetic, while in the vicinity of the permanent steel bar magnet M, precisely as B would be electrified by M, if previously charged by a machine: but, in the one case, there must be good insulation, while in the other none is requisite. The contact of M with B, would cause an electrical charge to be divided between them, whereas the same contact would cause the magnetic charge in B to be higher. In the one case the existing body loses power by contact, in the other it sustains no loss. That B is magnetized, may be shown by its attracting an iron nail or iron filings, if sufficiently near.

729. If several pieces of soft iron be placed successively in contact with each other, and with a steel magnet, as represented in the cut, figure 37, they will become magnets

Fig. 37.



by induction, but will lose the property entirely if soon separated. Yet, a piece of iron kept for some time in a state of induced magnetism, retains the property to a certain extent, In proportion, as a steel bar is harder, it is less susceptible of receiving magnetism, but is more retentive of this property. On account of its superior retentive-

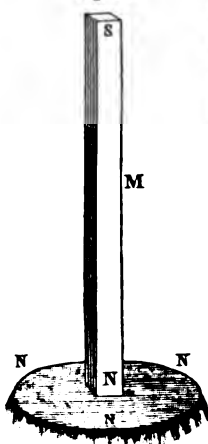
ness, all artificial magnets are made of steel, moderately hardened. Latterly our means of imparting magnetism to iron or steel have been immensely improved. A steel needle, or bar, may be permanently magnetized by drawing it, from one end to the other, over either pole of a powerful magnet. The magnetism at the end which moves towards the pole, becomes the opposite of the pole thus approached. If drawn from end to end in the same direction over the other pole, the magnetism will be enfeebled, if not destroyed or reversed; if contrarily, it will be confirmed, if not strengthened. Hence, there are two ways of producing the same results, *drawing similarly over the same pole, or dissimilarly over different poles.*

Fig. 38.



joining figure. Each particle of the filings becomes a magnet, having of course a south and north pole. The magnets thus created, arrange themselves in files, in consequence of the attraction between their oppositely magnetized extremities.

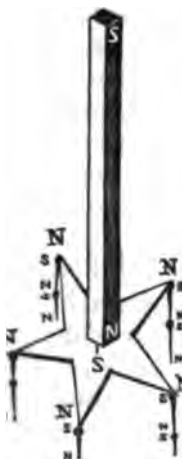
Fig. 39.



731. In the files thus formed by the inductive influence of the north pole of the U magnet, each little magnet will have its south pole the nearest, while in the file formed by the south pole of the U magnet the files nearest the latter, will have their north poles nearest. Hence, the extremities of the files acquire opposite polarities which are at the same time the opposites of those of the poles, with which they are respectively associated, and hence the extreme ends converge towards each other when sufficiently near.

732. Figure 40, serves to represent the magnetic power, given either to a disk or to a star of sheet iron, by applying to it

Fig. 40.



about its centre a pole of a magnet. By the polarity thus induced, several nails may be suspended as represented at N, N, N, N. To the disk a fringe of iron filings is attached. This power only endures so long as the magnet is applied.

733. If a prism of iron be attracted by a permanent magnet at either pole, the north pole for instance, the prism is converted temporarily into a magnet, acquiring at the place of contact a polarity the opposite of that of the pole to which it is presented. In other words, it acquires a south polarity, when it is presented to a north pole, a north polarity when presented to a south pole. Meanwhile, the other end of the prism acquires the same polarity as the pole by which the charge is effected. Hence, when in contact with two equally powerful bar magnets, as represented in figure 42, a prism of soft iron will be attracted with more force than the sum of their separate forces.

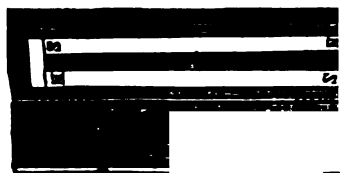
Fig. 41.



734. Further, if after having attached a prism of iron to the north pole of one bar magnet, and the south pole of the other, on bringing the two poles remaining free into contact with each other, or with a second prism like that above mentioned, the attractive power of the four poles will be more than twice as great as that exercised by either pair\* when the others are without due communication.

735. Hence the superiority of the power of one duly magnetized bar in the shape of the letter U, fig. 41, over two bar magnets. A magnet, thus formed, is called usually a horse-shoe magnet, from its having some resemblance in shape to a horse shoe: but preferably on account of its greater resemblance to the vowel U, it has of late been called a U magnet, by Dr. Page, and others.

Fig. 42.



\* Fig. 42, will convey a correct idea of two bar magnets as they are advantageously kept in a box with two armatures usually called keepers, on account of their sustaining the magnetic power when kept in contact with the poles as represented.

736. Agreeably to the state of soft iron attached to both poles upon them inductively, so as to *heighten* their power, since it is appended to it is gradually increased to a certain point. One always accompanies a U magnet armature. Some keepers have attachment of weights.

Fig. 43



737. Thus the keeper or armature shoe magnet is attached. The force can be perceived, combined, with the same side. Thus the magnet holds weight.

738. Under electrical induction, it will be seen that the means of affording a compound character to electrical discharge, but of which, the effect resembles the shock given by small pairs.

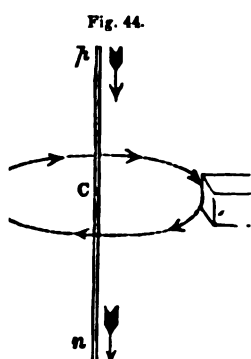
#### REACTION OF MAGNETS WITH

739. The student has been observing deviations of a magnetic needle under the influence of an electrical current. It was expedient to make a preliminary experiment of detecting the currents resulting from electro-magnetic influence (306).

740. In order to form an idea of an electrical current which is assumed could it be free from the influence of gravitation and magnetism, let us suppose on the pivot of his watch a needle, the north pole points, to be attached to the hands, and at right angles to it

which the motion usually takes place in clocks and watches. If a galvanic current be supposed to flow through a wire passing from the student's eye, through the pivot, the situations of the arrow, during one revolution of the end, will give him an idea of all the positions which the needle, when carried round the wire, would assume, relatively to the galvanic current.

741. Supposing the current to be reversed, to flow towards the eye, it is only necessary to imagine the movement of the hand reversed, and the arrow head pointing in the opposite direction, to give an idea of the positions, and the directions, which the needle would then be found to assume if carried round the galvanized wire.



742. Suppose *p*, *n*, fig. 44, to be the axis of a circle *C*, and that a current is flowing through the axis in the direction of the arrows. The arrow heads in the circumference show the direction in which as many magnetic needles would point if exposed to no influence besides that of the current. When the current flows from *N* to *P*, the relative position of all the needles will be the reverse of those represented.

743. It is not possible to contrive any apparatus, which will illustrate the reactions of a current and needle, excepting the three instruments known severally as the compass, the astatic, or the dipping needle. These serve to illustrate the phenomena only when they take place in an horizontal or a vertical position. Yet from the results obtained from these, an idea may be formed of those which would ensue in any other positions in which needles could be situated.\*

744. Figure 35, already given, represents the needle in its usual form. But the directive influence of the earth is avoided by associating two needles as in the subjoined figures, so that there is at either end a pole of each kind. If these be of equal energy, when thus combined reciprocal neutralization ensues, as respects their reaction with terrestrial magnetism. Such a needle is called astatic. When galvanic current flows either above or below an astatic

\* See engravings and descriptions of galvanometers.

needle, excepting that as one is nearer to the current than the other, they will be neutralized no longer.

Fig. 45.



Fig. 46.



Fig. 47.



ence of the

rent is ma

tatic pair, i

rates with

745. Fig

needle, in

suspended,

south pole a

means, if th

erful, the in

is neutraliz

on the othe

746. Figure

needle in an

two slender U

747. In the

ters needles ar

hair or filamen

cocoon. By th

the earth over

ized. In anoth

needle moves i

show that po

which cause

needle (35) t

before charg

placing it, th

tudes will p

This tendenc

by a counter

ferre with the

ing the north

to indicate an

ure 46, repre

illustration o

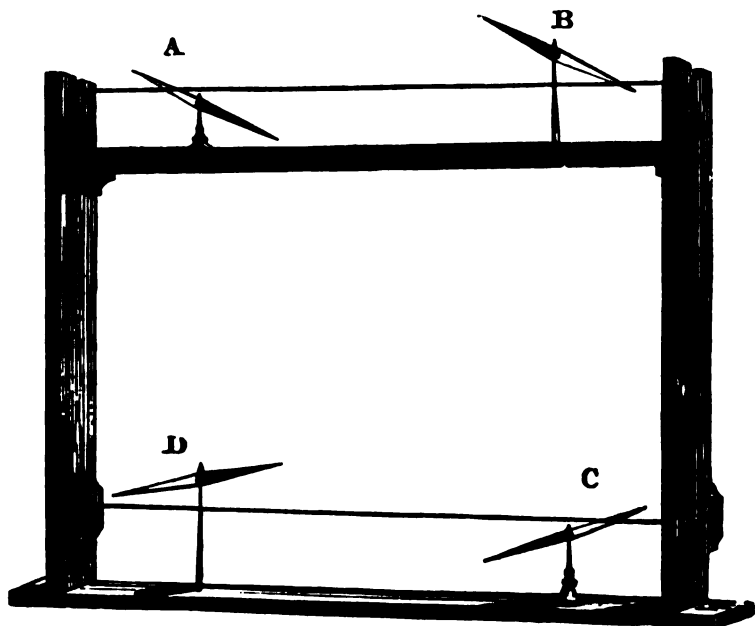
called the dip

of degrees wh

zontal level, i

748. The following engraving represents an apparatus, by means of which, four needles A, B, C, D, are simulta-

Fig. 48.



neously exposed to the influence of the same current, in respect to which they occupy different situations. Of any two needles, of the four, one of which is above the other below the current moving the same way, the poles will be seen discordantly directed. Of course any two of the four of which one is above the current moving one way, and the other below it, while moving the other way, will agree.

749. Accordance in the direction of needles exposed to the same circuit, is found only when the situation relatively to the current, and the direction of the current are alike, or where diversity in one respect is compensated by diversity in the other. In order that the currents thus moving in opposite directions should not counteract each other, it is necessary that two or three feet should intervene between those portions of the wire in which they take place.

750. The apparatus must, in order to show the phenomenon, have the wire in the plane of the meridian, so as to have the needles parallel to it; as, when uninfluenced

by the current, they place themselves so as to coincide with the meridian plane nearly, or, in other words, so as to point north and south.

751. The necessity which exists, of performing the experiment so as to avoid every injurious influence from terrestrial magnetism, ought not to create the idea that the phenomenon is dependent upon that magnetism. With astatic needles (44, 45), in which the polarity of one needle is so counteracted by that of the other, as to render the two indifferent to the polarity of the earth, the deviations may be produced without reference to the meridian.

752. The magnetism imparted to a coil by a galvanic current, agreeably to an observation first made by Am



père, was ingeniously illustrated by De la Rive, by causing such a coil to float together with the galvanic pair, of which it formed the connecting wire by means of a cork, as represented by fig. 49. C and Z are small plates of copper and zinc, above which the coil is supported, the ends being soldered severally to the plates. When the whole is made to float upon acidulated water, galvanic current passes through the coil from the copper to the zinc plate. Under these circumstances the coil will react like a magnet with either of the poles of a magnet sufficiently approximated, so as to cause the whole apparatus to be apparently attracted or repelled.

Fig. 50.

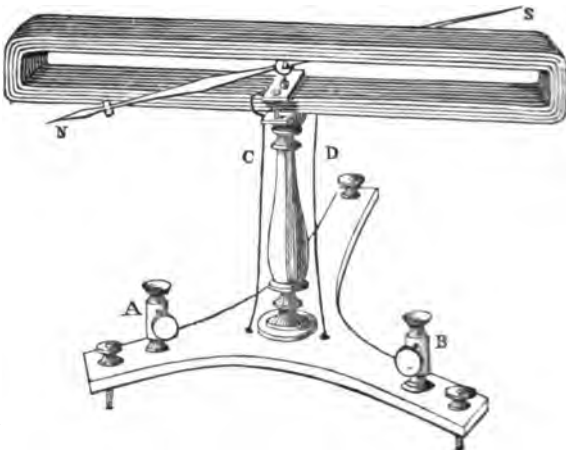
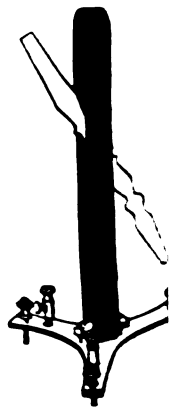


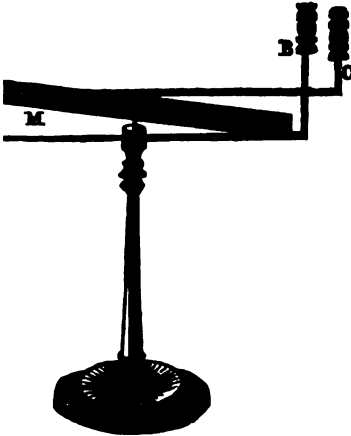
Fig. 51.





Two forms of the galvanometer (50, 51), are illustrated by the preceding figures, one of which represents the situation of the needle when placed in a horizontal, the other in a vertical plane. Figure 51 corresponds with the dipping needle; figure 50 with the compass needle.

Fig. 52.



754. The rationale of these instruments may be made evident by the more simple form represented by figure 52. In this the wire makes but one circumvolution, as in the larger apparatus, fig. 49. The influence of the simple current being understood, it will be easy to conceive, that if the needle were subjected to two such circuits, the effect upon it would be arithmetically greater as the number of such circuits acting upon it from an equally favourable position. Consistently, Schweiger, by multiplying the circuits or circumvolutions, produced the famous instrument in question, appropriately called a

galvanometer, but not as to a designation of the use to which it is applicable.

In multiplying the circumvolutions, it is not necessary to multiply the batteries by which they are supplied, since, when formed of a continuous helix the first and the last may, from the same battery, be supplied, if not at the same time, with an interval almost infinitely small. Suppose each circumvolution to measure a foot in circumference, twenty-thousand would be only half a mile, and this distance would be gone in less than the five hundred thousandth part of a second, agreeably to the inferences of Wheatstone, supposing them applicable to currents of intensity, as well as those of the statical kind.\* For a galvanometer of the highest sensibility, see Melloni's thermo-multiplier, the head of *Thermo-electricity*.

*Galvanometer or Multiplier of an unusually large size, made of Strips of Tin wound in a Coil with interposed Strips of very thin Paper.*

The engraving represents a large multiplier, or galvanometer, the needles of which are each about eighteen inches in length. The instrument is furnished above with a circle graduated into 360 degrees. Agreeably to the usual construction, the needle, being within the coil, is subjected both above and below to the concurring influence of a current passed through the coil. Under these circumstances, the needle is situated in the apparatus represented by the adjoining figure. In the position which the upper needle occupies, the influence of the lower portion of the coil, so far as it operates, must counteract that of the upper one. Yet when the lower portion of the metallic coil is at a distance from the upper portion of about half the length of the needle, and this is situated very near to the upper portion, here represented, the influence of the latter may so far predominate as to make the indications very nice; while they are much more easily seen and estimated by means of the graduated circle, when, as in the situation of the upper needle, nothing intervenes between it and the eye.

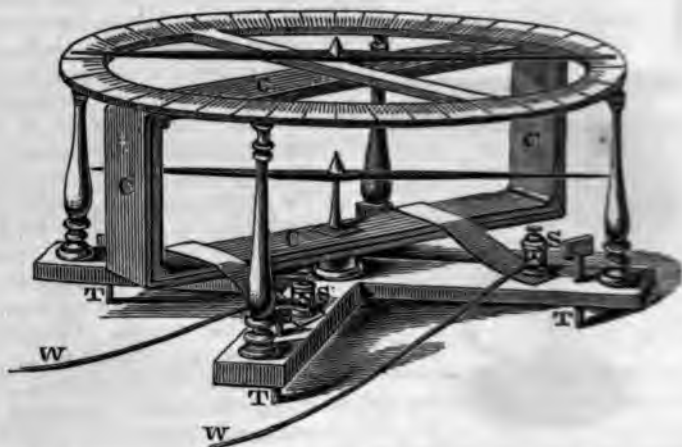
Another instrument of the same dimensions, I have used only a semicircle for the scale, which, excepting the appearance, answers as well.

The wire, a coil of tin foil of about an inch in breadth, and eighty feet in

*Ampère's Revolving Battery.*

756. The most simple process for creating a rotary motion, by means of the reaction between an electrical current and a magnet, is that in which

Fig. 53.



length, separated by thin paper, may be used, but a copper wire of No. 16, and about 180 feet in length, coated with shell lac varnish, will be more efficacious.

The coil of tin-foil or varnished copper wire, is wound about the parallelogram C, C, C. The ends of the coil are severally soldered, or screwed, under the base of the galleys screws, S, S.

When both needles are placed upon the pivot at the same time by the top of their similar poles, they will diverge from the meridian unless they be in a reversed situation, in which case they will both appear as in the engraving, the pole of one needle pointing north, the north pole of the other, south. When these circumstances, a discharge is made through the surrounding coils. The consequent movements are very striking.

The clean surfaces of disks of zinc and copper, each an inch in diameter, and by paper moistened with pure water, are sufficient to move the needles. The wires, W, W, are used for the purpose of connecting the disks with the poles of the wires. They are attached to the instrument by galleys screws, S, S.

The level of the machine is preserved by the aid of four screws, of which three can be seen in the drawing at T, T, T.

*Rotary Movements arising from the Reaction between Magnets and Galvanic Currents.*

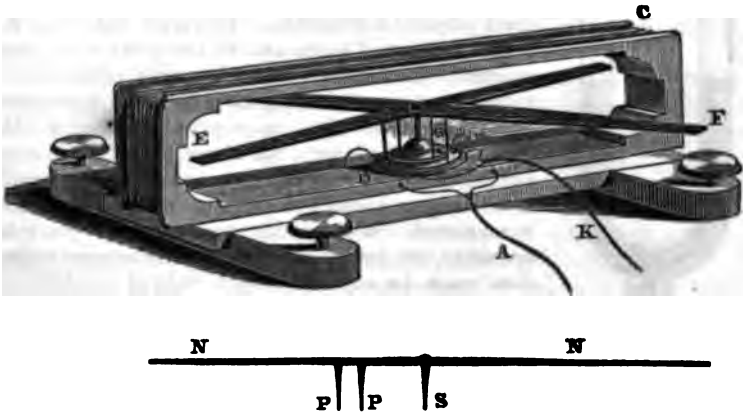
**ENGRAVING AND DESCRIPTION OF A ROTARY MULTIPLIER**

*Or one in which one or more Needles are made to revolve by a Galvanic Current.*

The preceding engraving represents a rotary galvanometer, or multiplier, contrived in November, 1836, and which must have value as an additional amusing, if not to the useful implements of science. It is well known that passing a temporary discharge through the coil of a multiplier, the needle is made to perform a revolution, whereas if the current be continuously applied, movement is checked as soon as the situation of the poles is reversed. To produce a permanent motion, the discharge must be allowed to take place only when the poles are in a favourable position relatively to the excited coil. This is obtained by means of two pins, descending from the needle perpendicularly, to enter two globules of mercury, communicating, on one side, with a galvanic pile, the other with the coil of the multiplier. In the next place, by winding on a first coil, another of similar length, but in a direction the opposite of that in

the galvanic triad, by which the current is generated, is made to revolve about the pole of a magnet, which serves as a support. This is exemplified by what has been called Ampère's rotating battery, of which figure 55, on the following page, will afford a satisfactory idea.

Fig. 54.



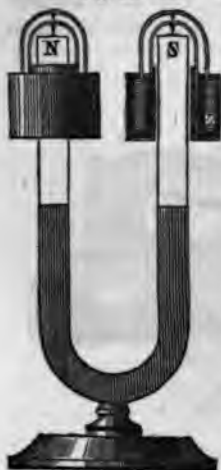
the first coil was wound, I was enabled, by two other globules, situated so as to communicate severally with the lower ends of the pins, at the opposite side from that on which the first mentioned globules were, to cause an impulse at every semi-revolution.

The one coil being wound to the right, the other to the left, the alternate effect of each upon the needle was similar in opposite parts of the orbits described by the pins. Lastly, a second needle, furnished with pins in like manner, being fastened at right angles to the first, so as to form with it a cross, as represented in the engraving, each needle is made to receive two impulses during every revolution. Hence one of Daniell's sustaining batteries, as made by Newman, is quite adequate to cause a revolution as rapid as consistent with a due degree of stability in the mercurial globules employed.

One end of each coil, by means of the branching wire A, communicates with one pole of the galvanic pair; the other ends of the coils terminate in mercurial globules contained in cavities on opposite sides of the wooden disc G, upon the centre of which the spindle of the magnetic needle rests. The branches of the wire K proceeding from the other galvanic pole, terminate in globules situated in the vicinity of those above mentioned, so that as the needles revolve, the pins proceeding therefrom perpendicularly may touch a pair of the globules first on one side and then on the other. Whenever this contact takes place, the circuit is completed, and a discharge is effected through one or the other of the coils of the multiplier.

Supposing E and F to be north poles, a discharge through one of the coils will cause E to move off a quarter of a circle, or more. As this ensues, the pins of F will come in contact with the globules which those of E touched before. Of course F will be propelled so as to cause the pins of E to reach the pair of globules at G, which, completing the circuit of a coil wound in a way the opposite of that first mentioned, concurs with that coil in its influence, so as to promote the rotation previously induced. The same result ensues when the pins proceeding from F, come in contact with the globules situated at G, and when E returns to its original starting point. It follows that by a repetition of the process the galvanic action is sustained. The phenomenon is as well illustrated by employing the single needle, N, N, as by two, but the most pleasing and energetic effect is produced by the crossed needles. In this simple form the spindle on which the needle rests and revolves is represented at S; the pins at P, P. Each coil, consisting of copper bell wire, is about thirty feet in length, and is contained in the groove C. The frame of the multiplier is constructed of mahogany, and is levelled by the milled headed screws, on the ends of which it is supported.

Fig. 55.

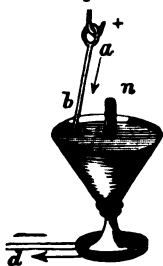


When the apparatus is in operation, the interstices between the copper cylinders must be supplied with a diluted mixture of nitric and sulphuric acid. A galvanic current taking place in each little battery through the supporting arches from the copper to the zinc (320), the cylinders revolve, the zinc and copper in opposite directions, as respects the movement of the two batteries, the similar cylinders move oppositely, the dissimilar cylinders move alike.

Fig. 56.



Fig. 57.



757. Two concentric cylinders of sheet copper, one about three-eighths of an inch larger than the other, are united by a flat ring of the same material, so that the latter forms a bottom, while there is between them an interstice of three-eighths of an inch. The inner cylinder is open and furnished with an arch of copper, at the summit of which there is a pivot pointing downwards. This pivot rests upon a agate cup seated upon one of the poles of a steel magnet. By means of another arch of copper a cylinder of zinc is supported within the interstice, resting by means of an appropriate pivot on a little concavity in the lower arch above described, as supporting the copper cylinders. Upon the other pole of the magnet another similar apparatus of cylinders is supported. When the apparatus is to be put in operation, the interstices between the copper cylinders must be supplied with a diluted mixture of nitric and sulphuric acid. A galvanic current taking place in each little battery through the supporting arches from the copper to the zinc (320), the cylinders revolve, the zinc and copper in opposite directions, as respects the movement of the two batteries, the similar cylinders move oppositely, the dissimilar cylinders move alike.

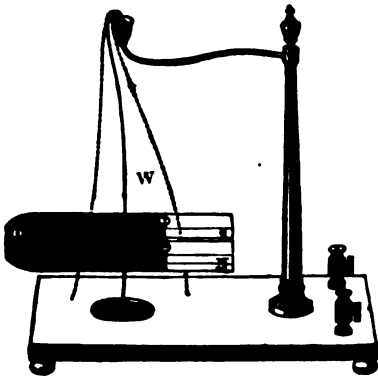
758. A magnet, *n s*, being attached, as in figure 56, by a silk thread, to the centre in the bottom of a cup of mercury, so as to float in that metallic liquid, a wire, *a b*, is fixed over it vertically, so as just to enter the mercury for a small depth. The metallic support of the wire is connected with one pole of a galvanic battery, the mercury with another. In this case, the upper end of the magnet, while swimming in the mercury, revolves about the wire from right to left, or from left to right, accordingly as the poles of the magnet, or the connections with the galvanic apparatus, may be varied. If, on the other hand, the magnet be made immovable, while the vertical wire is upon a universal joint, the wire will revolve about the magnet, and be able to change its direction, in the same way, as the moveable magnet was actuated, with respect to the wire.

759. The letters *n* and *s*, and direction of the arrows, in either of the adjoining figures, representing the apparatus alluded to, show the relative situation of the poles of the magnets, and direction of the current requisite to produce a revolution from right to left. In either apparatus a reversal of the relative position of the poles, or of the direction of the currents, will reverse the rotary motion. Of course *n* designates the north, and *s* the south pole.

760. When one end of a wire is fastened to the axis of the pole of a magnet, leaving the other end free, it will revolve about the point of attachment as a centre of motion, and in like manner, if the magnet is fastened

that one end to a point in the axis of the wire, the free end will revolve about the wire, because in either of the cases, whether it be that of the wire or magnet, an escape from one point of collision existing in the circle, throughout which the conflicting influence prevails, only carries it to another such point. Thus the point of attachment, about which the motion takes place, becomes a centre, about which either the magnet or the wire revolves, while making Ixion like efforts to fly from inevitable collision.\*

Fig. 58.

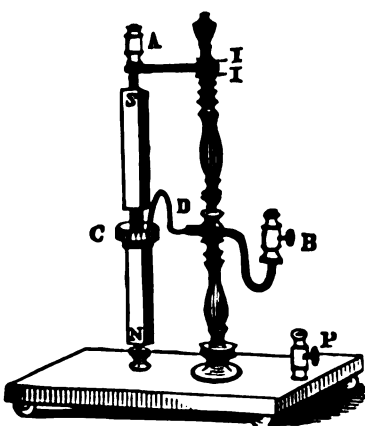


761. Let the end of the wire W hanging from a metallic bracket, which communicates with one of the set screws on the right of the platform, enter some mercury, occupying a cavity in the latter, which has a metallic communication with the other set screws. Under these circumstances, as soon as the set screws are connected with a galvanic battery in operation, the end of the wire flies out of the mercury, but the circuit being thus broken, the end of the wire soon falls again into contact with the mercury, and from the same cause as at

\* I here quote from Daniell's Manual a very interesting illustration of the reaction of a galvanic current with a bar magnet.

"Magnet revolving round its own Axis.—The instrument represented in figure 59 is designed to show that the action between the current and the magnet takes place

Fig. 59.



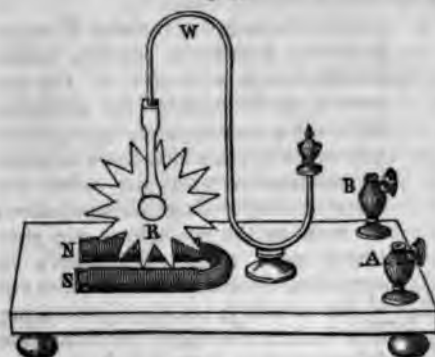
equally well when the magnet itself forms the conductor of the electricity. The lower end, N, of the magnet, being pointed, is supported on an agate at the bottom of a brass cup connected under the base-board with the binding screw cup, P. The upper end, S, is hollowed out to receive the end of the wire fixed to the cup, A; the brass arm supporting this cup is insulated from the brass pillar at I, I, by some non-conductor of electricity. To the middle of the magnet is fixed a small ivory cistern, C, for containing mercury, into which dips the end of the wire, D. Thus the magnet is supported with its north pole downwards, and is free to rotate round its vertical axis. A little mercury should be put into the cavity at S, and into the brass cup at N, and the ivory cistern be filled sufficiently to establish a connexion between the magnet and the wire, D.

"On connecting the cups, A and B, with the battery, the current will flow through the upper half of the magnet, causing it to rotate rapidly. If the cups, B and P, form the connexion, the current will traverse the lower half, equally producing revolution of the magnet. Now connect A and P with the battery, and no motion will result, because the electricity passes through the whole length of the magnet in such a manner, that the tendency of one pole to rotate is counteracted by that of the other to move in the opposite direction. Connect B with one pole of the battery, and A and P both with the other pole. The magnet will now revolve, since the current will ascend in one-half of its length, and descend in the other."

first, again flies out. Thus an alternate motion is produced and sustained as long as the current is continued.

### *Barlow's Revolving Wheel.*

Fig. 60.



ism, another takes its place, and of course encounters the same treatment. Every tooth being successively affected in like manner, the wheel revolves as long as the current endures. It is not necessary to the motion that the circumference be serrated, but it serves to make a pretty spark at each contact. The endurance of light thus arising, is too brief for the wheel to make a perceptible movement while it lasts. Hence, when the instrument is illuminated only by its own scintillations, it appears to be at rest, however rapidly it may revolve. It is computed that eight sparks in a second give the effect of a continuous illumination, and as the wheel gives more than these, it appears as if seen by a continuous light.

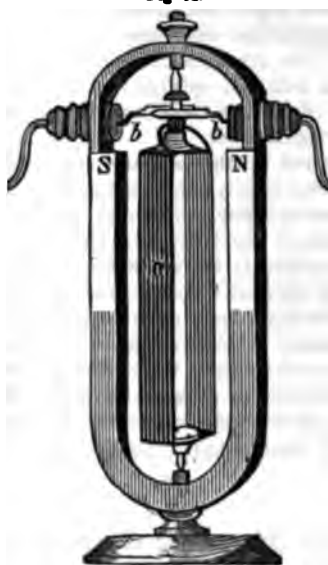
### *Explanation of the Motions produced by means of the Apparatus described in the three preceding pages.*

763. It has been shown, that the reciprocal reaction between a magnetic needle free to move, and a wire transmitting a galvanic current, is such that the former will strive to assume a position at right angles to a line parallel to the axis of the wire. Of course, as action and reaction are equivalent, the wire, if free to move, while subjected to the influence of a stationary needle, or other magnet, will arrange itself so as to produce the same relative position between the two bodies as when the wire is stationary, and the needle free. But if freedom of motion exist only at one extremity, whether of the needle or the wire, the motion can only take place at that extremity. Yet if the movement hence arising be not such as to interrupt the galvanic current, or be such as to permit its renewal as soon as discontinued, the consequent movement must be continued or repeated; it may be productive of rotary motion, as in the case of figures 54, 55, 56, 57, 59, or of alternate motion, as in the instance of 58.

762. The apparatus represented by figure 60, is called Barlow's revolving wheel, from the name of the inventor, the wheel being situated between the jaws, either of a steel magnet or an electro-magnet, and made the medium of the galvanic current, any tooth in contact with the mercury in the cavity under it, is actuated in the same way as the wire in the experiment above described (762). But when agreeably to the same law, one tooth flies from collision with the magnet.

### Revolving Rectangular Coil.

Fig. 61.



B  


764. As in the galvanometer of Schweiger, the force of the conflict between the dynamic polarity of the current, and the stationary polarity of the needle, is multiplied by reiterating the presence of the former in the coiling of wire through which it has to pass, in order to perform its circuit, so the instrument of which figure 61 is a representation, is an apparatus in which a current transmitted through the rectangular coil, between the jaws of the magnet, is made to react with the magnetic influence of the latter, and strives to escape therefrom, in order to assume the position in which there will be least interference. This takes place when the plane of the coil is so situated as to be at right angles to a line passing through the centre of each pole.

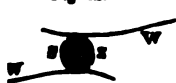
65. In fact the coil becomes a magnet, (752,) and of course tends to angle itself, as would a magnetic needle similarly situated; but, by means of a contrivance called the pole changer, described below, in making a semi-revolution to effect this arrangement, the direction in which the current goes through it is reversed, and consequently a different impulse is given, causing another semi-revolution. No sooner is this made than impulse again changes. Thus a continuous revolution is produced as long as the current endures.

### Of Page's Pole Changer.

66. In some cases, in order to produce opposite impulses, it is necessary to cause a galvanic current to flow alternately in opposite directions, in order, as it will hereafter be seen, it is an object to render an alternating current constant in its direction. For these purposes the following contrivance was devised by our countryman, Doctor Page, and executed by Daniel Reis, jr., the highly ingenious artist, to whom we owe the successful fabrication of a variety of electric, galvanic, and electro-magnetic apparatus.

67. The apparatus in question being employed to reverse the polarity of the electro-magnet in the apparatus last described (767), the following explanation is given in reference to the use of it therein made. The pole changer, figure 62, consists of two small segments of silver S, S, fixed on opposite sides of an axis of which a section is represented in the figure. These pieces are not in contact, and are sufficiently insulated from each other, and from the

Fig. 62.



axis. Of the two ends of the coil, situated between the legs of the magnet represented, one is soldered to each segment. By means of a wooden handle, of which the polar ends S, N, of a U magnet are the abutments, two

wire springs, *b, b*, are so supported and insulated, that through the intervention either of two cups of mercury, or two set screws, at *B, B*, they may be made to communicate at pleasure with a galvanic battery. The free ends of these wires are made to press against the segments of silver with sufficient force to make a good contact. The arrangement is such, that the respective contacts of the semi-cylinders with the springs will take place when the coil *C* is, as represented in the figure, at right angles to a plane passing through the axes of both legs of the magnet.

768. The apparatus being thus prepared, let the mercury cups and of course the wire springs, be in communication with a competent battery, consequently the current will from one semi-cylinder, enter one end of the coil, proceed through the circumvolutions of the latter, and go out of the other end of the coil to the other semi-cylinder; but if the coil be turned half round, the segments, and the ends of the coil attached to them respectively, will have their electrical states simultaneously reversed, creating in the sides of the coil a corresponding change of electro-magnetic polarity. Thus when the coil is turned from the position into which the polarities would bring it, in seeking to regain that attitude, it reverses them. This causes it to make another half revolution, which equally operates to reverse the propensity to change, and thus rotary motion is induced as long as the current is sustained.

### *Attraction and Repulsion between Electrical Currents and the Movements thence arising.*

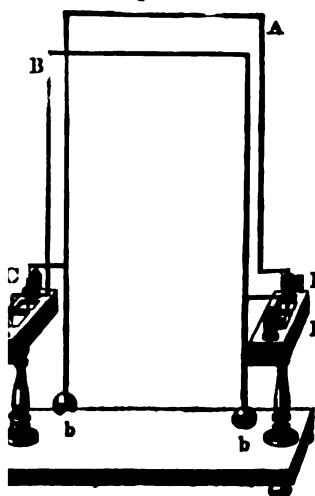
769. Not long after Oersted's discovery, it was ascertained by Mr. Ampère, a French philosopher of celebrity, to whose inventions and theoretic suggestions, electro-magnetism is pre-eminently indebted, that wires, completing the circuit of different galvanic batteries, would attract and repel each other; but not in a mode analogous to electrical reaction, since it was between the bodies, similarly excited, that the attraction was observed, while the repulsion took place between bodies dissimilarly excited. Electrical indications are obtained only, when the poles of the generating apparatus are unconnected, those afforded by the galvanized wires, were the consequence of their connecting the poles of the galvanic apparatus.

770. Figure 63, represents an apparatus, contrived for the purpose of shewing the reaction between wires subjected to galvanic currents.

771. Two copper wires, *A, B*, are supported parallel to each other, in such manner as that their upper parts may move freely towards each other, so as to touch, or in the opposite direction so as to become more remote. These wires are supported on points, which rest on the bottoms of cavities replete with mercury, being amalgamated so as to insure a perfect contact with that metal. By means of the little metallic balls, *b, b*, which may be lowered or raised by screwing, the centre of gravity of the wires may be so adjusted as to keep them perpendicular, when undisturbed, and yet



Fig. 63.



render it easy for them to oscillate from a very slight impulse. The four cavities holding mercury within which the points rest, as above stated, have each a metallic communication with the set screws C, D, E, F, when E, F, are made to receive wires from the same pole of a battery, while the other two, C, D, communicating with the other pole, the current will go the same way through both of the wires. Under these circumstances they will attract each other, and come together; but if E and C, be made to communicate with the one pole, while D and F, communicate with the other, the current will flow oppositely in the wires, and they will move apart, as if actuated by repulsion. If the wires be made to oscillate by a timely opening and of closing the circuit, the motion will be increased.

*tion of one Coil of Wire within another, in consequence of the rapid eation and reversal of the Polarity arising from the change of direc- m in a Galvanic Current caused by Page's Pole Changer.*

Fig. 64.



772. The adjoining figure 64, is designed to illustrate by means both striking and agreeable, the powerful and rapid attraction, and repulsion, between wires caused by electrical discharges made through them alternately in opposite directions.

773. This apparatus has a close analogy with that already described figure 61, as to the means by which the polarity of the coil is imparted, and the direction reversed at every semi-revolution, by means of a galvanic current, and the pole changer (767). We have only to substitute for the U magnet and rectangular coil, two circular coils of the same material as the rectangular coil. Of the two coils, one is large enough to contain the other without touching, and being stationary, takes the place of the U magnet. The other, of a similar shape, does not differ from the rectangular coil; while it is perfectly similar, as respects the means by which it is supported on an axis associated with the semi-cylinders of the pole changer, and the office which it performs. In one case by polarities arising from a current, the rectangular coil is made to rotate by conflicting with the poles of a U magnet; in the other case the polarities arising in a circular coil from the same current, conflict with those arising from a current in another coil. In either case, seeking a non-conflicting attitude, it is disappointed by the consequences of its own efforts, and the perverting influence of the pole-changing appa-

### Of Electro-dynamic Induction.

1st. Under this head we may put *Induction of a Current upon it*  
 2d. *Generation of Currents by the Dynamic Inductive Influence of other Currents.*

#### Induction of a Current upon itself.

Fig. 65.



774. Figure 65 represents a coil of copper, in weight thirteen pounds, in width one and an half inches, length ninety-three feet. This is wound into a flat coil, of six inches in diameter, but, being insulated by a double coating of silk, there is no metallic contact between the turns of its circumvolutions. When the end of the coil thus formed, is presented, connected with one terminal of an active battery *e*, to the other of which a rasp *d*, is soldered, scraping the rasp with the free end of the coil, sparks and metallic detritus ensue with much more copious scintillation and louder snapping

than if the same scraping were to be performed with the termination of a conductor having a length no more than requisite to complete the circuit. Moreover, Henry, I believe, first observed, that an operator touching the rasp with one hand while holding the end of the coil during the scraping, would be subjected to a perceptible shock at each of the interruptions of the circuit, to which the sparks were indebted for their existence.

775. Under the circumstances of the experiment, described in the preceding paragraph, whenever the ribbon touches the rasp, the battery forms two circuits at command, one completed altogether by the coiled ribbon, the other in part by the person of the operator. Yet on account of the intensity of the current, the imperfectly conducting circuit formed by the human frame, will not be the mean of a perceptible discharge so long as another route afforded by the perfectly conducting copper ribbon is uninterrupted: but when the ribbon circuit is ruptured, a perceptible discharge takes place through that made up of the operator's person, the coil he holds, and the rasp which he touches.

776. By the premises, the direct action of the battery is wholly incompetent to produce any perceptible discharge through the operator. Consequently the shock, produced as described, and all the other characteristics in which the phenomena arising from the breach of the circuit when the coil is interposed, differ from those which appear when a short metallic conductor is similarly employed, must be ascribed to the intervention of the coil. It would seem, therefore, that the materials of the coil, both ponderable and imponderable, become coerced by the battery into an unusual state; so that, on the rupture of the circuit to which this state is due, the matter recoils towards its natural equilibrium, producing an electric charge of an intensity far above that of the parent stream sent through the coil from the battery. On this account, it would seem as if the discharge might be appropriately designated as a recoil current. The conductor, which is the channel of a galvanic current, is in an unusual

state of polarization, almost the whole of the phenomena of electro-magnetism seems to justify. This state, noticed by Faraday, was designated by him as an electrotonic. The tension arising from this state, or the energy of the effort to have it made by the matter in which it has been produced, appears to be greater when the conductor, being in the ribbon form, is wound up as a coil. Doubtless the proximity of the circumvolutions to each other, must cause a reaction between the similar polarities, tending to augment their resistance to the state imposed on them by the battery.

777. Analogous to the accumulation of power, above described as created within the ribbon coil, is that which arises in a voltaic series of sufficient intensity when the circuit is incomplete. Hence, agreeably to Henry's observations, the direct action of a series of high intensity, forming a circuit through a short conductor by sudden contact, resembles, as to intensity, the indirect action of a battery of low intensity, on breaking the circuit formed through a long conductor. In the one case, the intensity being due to the resiliency of the electrifiable particles of the conductor, is increased with its length to a certain point; in the other case, the intensity being due to the battery, the conductor cannot be too short: excepting that when the effect is measured by the current inductively created in another conductor, agreeably to the process next to be explained, this effect must be influenced by the length of the conductor, as well as the intensity of the current which it conveys.

778. It has been suggested (776), that the electrical discharge accompanied by a shock and unusually large and noisy spark which characterizes the process under consideration, is the consequence of the sudden effort of the matter of the coil, both ponderable and imponderable, to recover its natural equilibrium from a state of forced polarization within the coil. There is a rough analogy between this resiliency of the supposed imponderable current, and that which would ensue, if, instead of a copper coil dynamically electrified, a steel watch spring were wound up, to a certain degree of tension, and then suddenly liberated so as to be allowed to react.

779. But in the act of recoiling, if, by the discontinuance of the broad channel in which it may be generated, the current be diverted into a collateral channel, in which it must experience far more resistance, the animal frame of the operator, in the case in point, the concussion must be proportionable to the impediments, just as if a torrent by being suddenly dammed up, were forced into a circuitous channel, containing rocky obstructions.

780. In the instance of a principle, which moves with the inconceivable velocity which characterizes electrical discharges, the larger the mass which recoils, the greater the effect; but as to wind up a spring instantaneously, requires an activity in proportion to its length, the longer the wire in which the tension is to be induced, the greater the voltaic intensity required. Thus Henry found, that when a voltaic series, consisting of six pieces of bell wire, each one inch and an half in length, and an equal number of pieces of zinc, of like dimensions, were employed to excite a due electrical tension in a spool of wire five miles long, and one-sixteenth of an inch thick, the shock resulting from resiliency on the rupture of the circuit, was sufficient to affect twenty-six persons joining hands.\*

\* I quote here from Davis' Manual of Magnetism, an engraving and description of an instrument designated as the *Contact Breaker*. Supposing to employ this mechanism in the production of the phenomena, arising from a rapid rupture and renewal of a galvanic circuit, this explanation may be desirable to some of those who may witness the processes in which it may be used.

### Generation of Currents by the Dynamic Inductive Influence of the Currents.

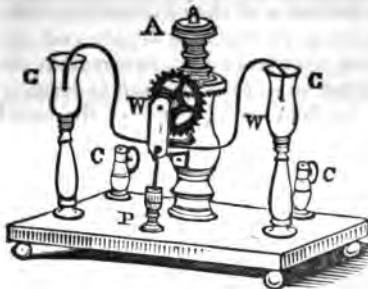
781. The power which an electrified body has to produce an opposite charge in another, has been explained under the name of "*Electrical excitement by Induction*" (E, 107). There is another species of inductive influence, to which allusion was made as dynamic induction (E, 120).

782. The attractive and repulsive influence of wires subjected to galvanic currents has been illustrated (771-2). To Faraday we owe the discovery, that there is such a reaction between the cause of electricity in any conductor, with the same principle in another, that under favourable circumstances a current in one may inductively produce a transient current in the other. Thus, when two long wires were associated in concentric circles, metallic contact between the circumvolutions being prevented by the silk with which the wires had been covered like bonnet wire, on making or breaking a galvanic circuit made through one of them, a transient current was produced through the other. This effect was detected by subjecting a needle to the dynamic discharge through a small hollow helix of wire, included in the resiliating circuit.

783. The following laws have resulted from Faraday's researches:—  
"1. During the time a galvanic current is increasing in quantity in a conductor, it induces, or tends to induce, a current in an adjoining parallel con-

It consists of a bent copper wire W W, which by means of clock-work motion by a spring, is made to vibrate rapidly, dipping its ends alternately into the glass cups G G, intended to contain mercury. The spring is wound up by turning the milled head A. The glass cups are open at the bottom to allow the mercury to come in contact with the brass pillars on which they are cemented. These pillars are both connected with one of the leading screw cups C C; the other cup communicates with a brass mercury cup P, into which dips a short wire connected with the vibrating wire. Sufficient mercury must be put into the cup P, to keep the end of the vertical wire covered, and enough into the glass cups to allow one end of W W to leave the mercury in a cup a little before the other end dips into its portion.

Fig. 66.



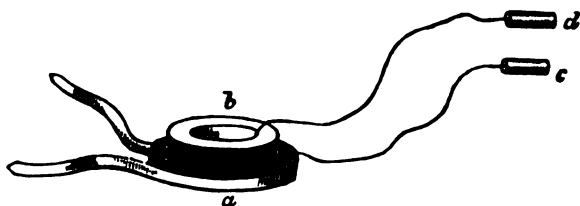
The Contact Breaker may be advantageously used in connexion with any of the instruments for affording sparks and shocks, which will be described under the following head. The current must be transmitted through the two instruments in succession, by connecting one of the cups C C with one pole of the battery, and the other cup with one of those attached to the spiral or other piece of apparatus the remaining cup of which is to communicate with the other pole of the battery. It is better to break the circuit mechanically in this way, than by means of any interrupting apparatus worked by the battery itself, as a considerable part of the power of the current is then expended in giving motion to the interruptor.

On making connexion in this manner with a flat spiral, and turning the milled head A to put the vibrating wire in motion, a brilliant spark will be seen at the rupture of contact, accompanied by a loud snap, and producing considerable combustion of the mercury. With a battery consisting of a few pairs of plates of any size, such as Dr. Hare's Calorimotor, the size of the spark will be greatly increased and the snap become as loud as the report of a Leyden jar. The shock will also be pretty strong, and may be increased by covering the mercury in the glass cups with a stratum of oil. A shock may be obtained, especially when oil is used, on closing the circuit as well as on opening it, though inferior to that given in the latter case. A faint spark is also sometimes seen when the wire dips into the mercury.

ductor in an opposite direction to itself. 2. During the continuance of the primary current in full quantity, no inductive action is exerted. 3. But when the same current begins to decline in quantity, and during the whole time of its diminishing, an induced current is produced in an opposite direction to the induced current at the beginning of the primary current."

784. Professor Henry, of Princeton, has shown that currents may be strikingly produced by induction, in the following manner. The circuit formed, through the ribbon coil, *a*, with the battery, figure 65, being alternately made and interrupted, as stated (774), a helix of coated copper wire of about 21 wire gauge, and of about 4900 feet in length, is subjected to the inductive influence of the coil, as represented in the adjoining figure, in

Fig. 67.



which the coils and helix are situated concentrically one upon the other, while separated by a plate of glass. The intensity of the resiliating current as measured by the shock, increases with the length of the helix employed, until the resistance to the electrical current consequent to the length, compensates the benefit otherwise arising. Yet, as might be expected, the length to which the circuit may be thus extended with advantage, *ceteris paribus*, is proportional directly to the numerical extent of the voltaic series employed (431).

785. The ends of two wires severally connected with those of the helix, being rubbed one against the other, while the circuit through the coil is alternately broken and renewed in rapid succession, sparks will be visible, and slight shocks may be felt through the fingers or tongue, on contact with the wires. When the ends of the wires are joined, the sparks and snaps, which can be obtained between the end of the coil connected with the battery while passing over the rasp, are much diminished in energy, and no shock can be received.

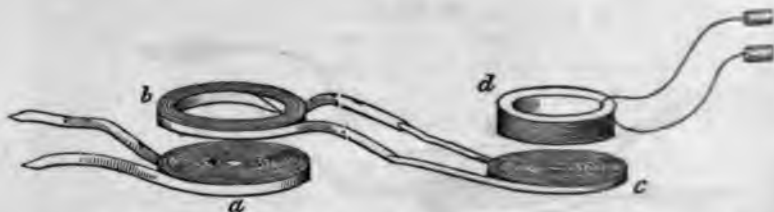
786. A delicate galvanometer being associated in the circuit with the upper coil, whenever the battery circuit is completed through the coil, the magnetic needle will be extensively deflected, but will immediately return to the meridian, a flow of a current through the wire of the galvanometer is thus indicated, which is nevertheless transient apparently. On opening the circuit, a similar transient deflection will occur in the opposite direction. No deflection occurs while the battery current is flowing steadily. The galvanometer should be placed at such a distance from the coil that the current through this may not affect the needle.

787. A sewing needle will be magnetized if placed within a spiral of wire of very small diameter, duly comprised in the same circuit as the helix. The polarity produced by the current which ensues on the completion of the circuit, will be the reverse of that communicated by the current consequent to its rupture. If both currents are allowed to act on the

needle, it will acquire little or no magnetism, as the magnetizing influence of one will counteract that of the other.

788. Instructed by Faraday, Prof. Henry has added many ingenious discoveries respecting the phenomena of dynamic induction; among these is the consistent consequence, that the transient secondary current, as above described, inductively produced in a second coil, was capable of being communicated conductively, so as to circulate through a third coil, which, acting inductively on a helix, was productive of a tertiary current of the same character, though feebler, as that produced when the helix is exposed to the inductive influence of the primary coil. Hence shocks will be received by

Fig. 68.



a person holding in each hand one of the handles, to which the ends of the helix are attached, as represented in figure 68. The process may be extended so as to produce, analogously, fourth and fifth currents. "Henry alleges that a shock was given, by means of a current of the third order, to twenty persons joining hands." Shocks extending to the arms were also produced by the process above mentioned, "with currents of the fifth order."

789. Of course, the characteristic efficacy of the primary current must be liable to vary with those of the galvanic apparatus employed in its production, and the length, width, and thickness of the ribbon employed. With a simple elementary battery of a given size, there must be a certain length, width, and thickness of ribbon, which will produce a maximum effect; and any deviation from this combination of requisites must be productive of deterioration. It follows, that with ribbons of various dimensions, there must be for each a degree of intensity and quantity depending on the number and size of the voltaic pairs, which will render the inductive power produced by its means, a maximum. Hence the sectional area and length of the ribbon, the extent of the oxidizable surface of the zinc, and the number of the series into which it may be divided, form variable elements susceptible of an almost infinite variety of complications. Each of these various complicate combinations must have its appropriate effect upon a secondary coil, having a given length and sectional area, but must vary with every change in either of these dimensions. In like manner, the characteristics of the current produced by the inductive influence of a second, a third, a fourth, or a fifth coil, or as many as may be employed with effect, must vary with their length, shape, and sectional area. Another source of variation arises from the distance of the inducing coil from that which is the subject of the inductive power, and also their parallelism, and the degree in which their axes may approach or recede from coincidence with one line. The directions of the currents, inductively incited, seems to have varied with the distance.

Fig. 69.

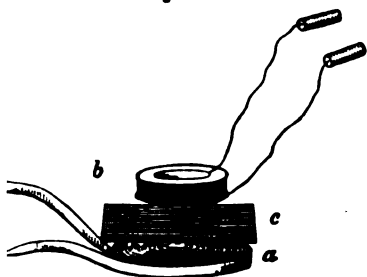
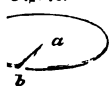


Fig. 70.



a sheet of metal, out of which a gore or sector has been cut, as represented in figure 70, does not impair the power of induction. Moreover, when from the corners of the gash made in a plate, by cutting out the gore, wires soldered thereto were duly extended and attached to the ends of a helix, in-

Fig. 71.



cluding a needle; to this needle, on subjecting the plate to the inductive influence of a coil duly excited by a battery as in the adjoining figure, polarity was imparted, which was such as to show the resilient current to be in the

direction as that in the inductive coil, *a*. This resilient current is considered by Henry as a secondary one, but it seems to me it is to the imitable current of which it is the resiliating effect, that the appellation of secondary should be applied.

91. I find that a sheet of zinc does not prevent the creation of a resilient current in my helix (793), sufficient to affect the gold leaf galvanoscope. I am under the impression that the plate acts by causing a diffusion of the inductive force, so as to reduce its intensity too low for causing shock.

92. The screening power above described, as displayed by a sheet of silk interposed between the first and second coil, equally availed, when an interposition was made between a second and a third, a third and a fourth, or a fourth and a fifth coil.

93. When a copper ribbon coil is made to act inductively on a long helix of wire, as illustrated in figure 67, the shock arising from the resiliating of the induced electrical tension seems, within an extensive boundary, to be greater in proportion as the wire is longer and more slender. I have employed a ribbon coil of about three inches and a half wide, and one hundred and ninety-six feet long, and a helix of coated copper wire, No. 21, of about twenty-eight pounds in weight, and a mile in length, furnished with light metallic handles. Although the helix may be supported at the distance of several feet above the coil, while the current of a calorimotor is gradually established and arrested within it, a person holding one handle of the helix wire in each hand, will receive shocks which augment in severity as the helix is approximated to the coil, and become intolerable when it is brought into contact with it nearly.

94. Figure 72 represents a helix such as described, situated as when it receives smart shocks, in consequence of the inductive resiliating influence of coil, *c*.

Fig. 73.



Fig. 72.



795. From the preceding statement, it appears that a current of great *quantity* may produce a current of great *intensity*. But Henry has shown that the converse is possible. The adjoining figure has been employed by him to illustrate the experiment by which the facts alluded to were established.

796. The tension *induced* by coil *a*, is conducted *conductively* to coil *c*, whence it is conducted *inductively* upon the helix *d*, producing *intensity* *conductively* transmitted to *e*, whence it *inductively* generates a current of *quantity* therein, sufficient to magnetize a needle included in a little spiral as represented.\*

797. Much labour has been bestowed by Henry in determining the directions of the current in different coils; but in this part of his investigation is too much abstruse and minute detail, but is connected with striking phenomena, to be introduced in a text-book. I am under the impression, that pointing out the consequences which theory would found on the idea that each current, inductively induced, must be the opposite of that which induces it, would give the direction of each generated in the coils and helices of figure 73.

### *Dynamic Inductive Influence of Statical Electricity.*

798. On this subject I will quote a few lines from Henry's Memoirs, published in the American Philosophical Transactions, together with the appropriate engraving.

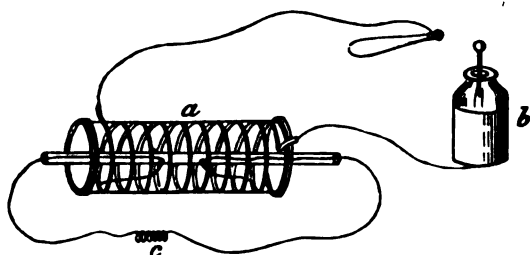
799. "The discovery of the fact that the secondary current, whilst it lasts but for a moment, could induce another current of considerable intensity, gave some indication that similar effects might be produced by a discharge of statical electricity."

\* It must be evident, from the experiments here illustrated, that the same electric power produces either quantity or intensity, accordingly as it is made to pass through the long and narrow circuits afforded by the wire helices, or the shorter and more ample channels afforded by the ribbon coils.



of ordinary electricity, provided a sufficiently perfect insulation could be obtained. To test this, a hollow glass cylinder, fig. 74, of about six inches in diameter, was prepared with a narrow ribbon of tin-foil, about thirty feet long, pasted spirally around the outside, and a similar ribbon of the same

Fig. 74.



length pasted on the inside; so that the corresponding spires of the two were directly opposite each other. The ends of the inner spiral passed out of the cylinder through a glass tube, to prevent all direct communication between the two. When the ends of the inner ribbon were joined by the magnetizing spiral, *c*, containing a needle, and a discharge from a half gallon jar sent through the outer ribbon, the needle was strongly magnetized in such a manner as to indicate *an induced current through the inner ribbon in the same direction as that of the current of the jar*. This experiment was repeated many times, and always with the same result.

800. "When the ends of one of the ribbons were placed very nearly in contact, a small spark was perceived at the opening, the moment the discharge took place through the other ribbon.

801. "When the ends of the same ribbon were separated to a considerable distance, a larger spark than the last could be drawn from each end by presenting a ball, or the knuckle.

802. "Also, if the ends of the outer ribbon were united, so as to form a perfect metallic circuit, a spark could be drawn from any point of the same, when a discharge was sent through the inner ribbon."

803. An analogous inductive influence to that observed in the case of a series of coils, of which the first in the series is made the channel of a galvanic discharge, has been noticed by Henry in the case of wires placed nearly parallel to each other, of which one is made the medium of a discharge from a battery of coated jars. Having, with my assistance, caused two such wires to pass round my lecture room, as near as possible to each other, without touching, the ends of one of the wires being severally inserted in cups of mercury, while the other wire was the medium of a discharge from my battery, shocks were received in the fingers when they were plunged in the mercury in the cups, at the moment of the discharge.

804. It is to discharges of this kind, as I conceive, that the souring of milk and beer, during thunder storms, may be ascribed.

805. It is not possible to do full justice to the speculations, experiments, and observations of Henry, in an elementary treatise: I therefore forbear to extend this account of them further.

806. As respects the hypothetical explanation, I have resorted, in common with Henry, to the conventional idea of electrical currents inducing other currents; but it will be hereafter suggested, in treating of the theory of electricity, that the phenomena may be the effect of waves of polarization

induced in that ocean of the imponderable material cause of electricity, which, in a state of excessive condensation, is conceived to occupy the space intervening between ponderable metallic particles, and at the same time in a state of greater or less density to pervade the creation.

#### INDUCTION OF MAGNETISM BY CURRENTS.

807. Soon after Ampère, in observing the reactions between electrical currents, made the first step in the branch of science last treated of, discovery was made of the power of such currents to impart magnetic polarity to a coil of wire, and of rendering a needle situated transversely to the current, magnetic.

808. This power of imparting polarity, was prodigiously increased, when the wire wound into a helix, was made to include the needle. By these means the influence of the current was reiterated, as in the instance of Schweigger's galvanometer.

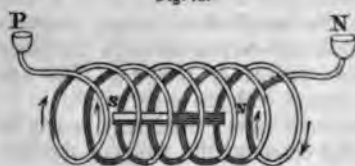


Fig. 75.

809. The adjoining figure represents a right spiral of copper wire, containing a rod of soft iron. The ends of the wire terminate within small cups of mercury. Thus situated, a discharge of the gal-

vanic fluid through the spiral cannot be made so transiently as not to impart magnetism to the bar. The current being from the cup, P, to the cup, N, the poles of the rod will have the character indicated by the initials, S and N; but either reversing the current, or substituting a left spiral, would reverse the character of the magnetism communicated to the rod.

810. The polarity given to the needle, when the current flowed one way, was found to be the opposite of that imparted when it flowed in the opposite direction. The current being conceived to proceed in the wire from positive to negative, the end of the needle pointing the same way, as the flowing of the current must receive north polarity, the other receiving consequently south polarity; but reversing the direction of the current, the polarity must be reversed. The polarity varied also, as the helix was wound to the right or the left, so that a left helix being used as mentioned above, the currents would have effects the opposite of those produced by a right helix.

811. In fact the same wire was found to acquire differ-

ent polarities, when different parts of it were made to occupy a succession of cavities in different helices, some wound to the right, the others to the left. A needle was magnetized when situated on the outside of a galvanized helix, but much less powerfully than when included discharges of statical electricity were found competent to produce magnetism, when substituted in the same processes, for those of galvanism, but the power imparted was comparatively very feeble.

812. Mr. Ampère, besides other interesting discoveries which my limits will not allow me to illustrate, and which it would be impossible to describe satisfactorily, most ingeniously caused the ends of a wire forming a helix to return through the axis of the helix, without touching it, to the middle, and, passing them out of the helix, one on one side, the other on the other side, they were made to form an axis, on which the whole might revolve. The different ends of the wire, thus arranged, being made duly to communicate with a galvanic battery, the helix was influenced by a magnet, as one magnet is affected by another.

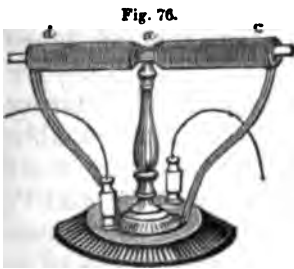


Fig. 76.

813. Two coils wound one to the right, the other to the left, as in figure 76, and made the medium of a galvanic current, in the usual way, will impart opposite polarities to two bars or rods of iron simultaneously introduced, one of them within the coil on the right, the other within that on the left. The polarity of the outer extremities will be similar, and the same is true of the ends near the centre. This may be shown by withdrawing and presenting them to the poles of an ordinary magnetic needle.

814. In this way if one bar be introduced so as to occupy the cavities of both spirals, it will have three poles, the middle having only one polarity, which will be the opposite of the similar polarity of the extremities.

### *Of the Electro-Magnet.*

815. A rod of iron, magnetised by a galvanic current, as above illustrated, is called an electro-magnet. Professor Moll perceived, that if a bar magnet was more powerful in the horse-shoe form, the same ought to hold in the

case of an electro-magnet. Hence he was led to construct an electro-magnet resembling that represented in the subjoined figure.

Fig. 77.



Fig. 78.



816. It consists of an iron rod in the shape of a horseshoe, on which copper wire of the size used for bells, covered by silk, is wound, from one end to the other. The electro-magnet thus made held seventy-five pounds while weighing itself only five pounds.

817. The quantity of wire employed in the construction of the electro-magnet represented by the preceding

figure is evidently inadequate to produce a high charge, yet the engraver may be more competent to convey a conception of the process by which a magnet is charged, than that of figure 78, which is closely covered with copper bell-wire, so as to be capable of acquiring from the same current proportionally much higher power. Of course it may be imagined that the cups at N and P in figure 77, are to be supplied with mercury, so as to make a connexion with the extremities of a galvanic battery. Yet I prefer set screws, for effecting such connexions.

### *Of Henry's Electro-magnet.*

818. The results obtained by Moll were eclipsed by those accomplished by our countryman, Professor Joseph Henry, of whom mention has already been made.

819. Of his celebrated electro-magnet, the following account is extracted from Silliman's Journal, vol. 21, 1833, page 400.

820. "A soft iron bar, two inches square, and twenty inches long, having the edges rounded, was bent into the form of a horse-shoe. Five hundred and forty feet of copper bell-wire were wound round it, in nine coils of six

feet each. These coils were not continued from one end of the magnet to the other, but each of them was wound round a portion of the horse-shoe about an inch in length, leaving the ends of the wires projecting, and properly numbered. The alternate ends were soldered to a copper cylinder, and the others to a small cylinder of zinc, containing only two-fifths of a square foot, and forming a voltaic arrangement with dilute acid. When the armature of soft iron was placed across the ends of the horse shoe, it was found capable of supporting 650 pounds: an astonishing effect for so small a battery, which required a charge of only half a pint of dilute acid. With a larger battery, the weight sustained was 750 pounds, which seemed to be the maximum of magnetic power that could be developed in that bar by voltaic electricity. It is remarkable, that when the ends of the wires were united so as to form a continuous wire of 540 feet, the weight raised was only 145 pounds."

821. Another magnet was made by Professor Henry, which held upwards of two thousand pounds.

822. Subsequently magnets have been made adequate to hold three thousand pounds.

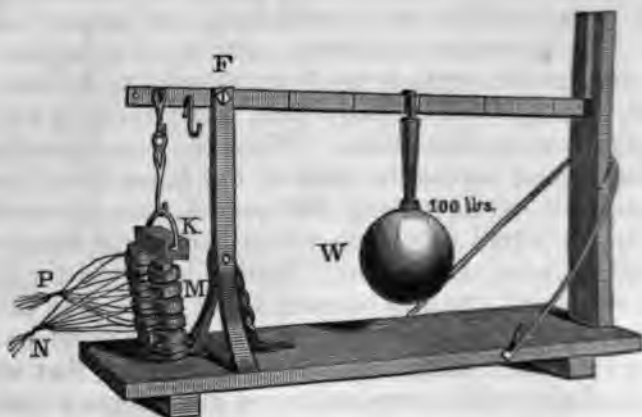
823. As soon as the current through the coils of an electro-magnet is arrested, the keeper, if loaded, falls off, since the magnetic power which remains, is extremely feeble. The rapidity with which the magnetic polarity is produced, destroyed, and reproduced, or reversed by shifting the direction of the current, is very remarkable.

824. The following figure represents a modification of Henry's electro-magnet, as constructed by me, soon after the account above quoted was published.

825. M is the electro-magnet, consisting of an iron cylinder, of  $1\frac{1}{2}$  inches in diameter, and 24 inches in length, bent so as to form a U. It has six coils of sixty feet of covered copper wire on each leg. K, the keeper, of which the sectional area should not be less than that of the bar of which the electro-magnet is formed. The keeper is suspended from a steelyard, divided into parts, each equal to the distance between the hook supporting the keeper and the pivot of the fulcrum at F. The iron globe W, weighs 100 pounds, and when slid to the fifth division necessarily acts on the keeper with a force equal to five times its weight. When excited by a calorimotor of two pairs, such as has been described, fig. 8, it has been necessary to add additional weight to increase the force to 750 pounds, before the separation of the keeper could be effected.\*

\* The coils are twelve in number, each comprising sixty feet of copper bell-wire, wound up with thin paper and shell lac varnish, to prevent metallic contact. They

Fig. 79.



*Of the Rapidity with which Polarity may be Reversed, and the consequent Rapidity of Rotary Motion thence arising.*

826. The attractive power above mentioned as imparted by an electric current to a cylinder or bar of iron in the U form, is rendered more surprising by the inconceivable minuteness of the time requisite for the induction, and reversal of the polarity on which it depends.

827. The alternations of attraction and repulsion resulting from the reversal of polarity, has been an object of much attention and experimental contrivance, with the view of obtaining an advantageous moving power machinery.

828. Previously to the career of Professor Henry, it was known that the most transient duration of a galvanic current passing through a helix would magnetize, or reverse the magnetism of an iron rod contained in the helix. This susceptibility of opposite magnetization was more presented to attention by Henry, and may be illustrated by a little machine, of which a description is subjoined.\*

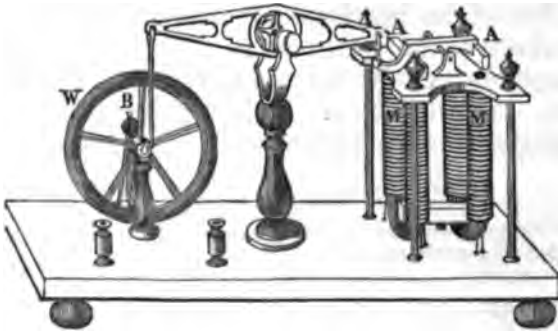
were severally wound upon an iron cylinder of the same diameter as that of the electro-magnet, previously surrounded with thick paper so as to increase the thickness of the little. In consequence of this precaution the bore of the coils was sufficient to allow them to be transferred with ease, from the iron cylinder to the core of the magnet. Six were thus affixed to each leg. In order that such a set of coils should coöperate, when all are wound one way, so for instance, as to form right and left helices, all the beginnings must communicate with one pole, all the endings with the other. To facilitate this, the analogous extremities are soldered together as represented in the figure. The same rule must be observed if they be all wound to the right or left. A right and a left coil, may be made to coöperate in producing the same polarity, if each beginning is applied to the same pole as each ending. By a beginning we mean that extremity at which the coil is begun to be wound: by an end we mean that extremity at which the winding terminates.

\* *Reciprocating Engine.*

Figure 80, may afford a good idea of a reciprocating machine working on the principle suggested by Henry. The polarity of the two upright electro-magnets

829. *Davenport's Machine*, which drew so much attention, added nothing to our knowledge. The change from an alternate to a rotary motion, was an easy step made independently by Richie and others, as well as himself. As respects its efficacy as a moving power compared with an alternating motion, it was a step towards the rear, which any one well acquainted with the nature of the peculiarity of the powers of electro-magnets and with mechanics, would not have taken. In my opinion, the great defect of this power is, that its force is exerted through a very minute space. For its advantageous exertion it is requisite that the surfaces of the armature and those of the poles of the electro-magnet be parallel and exactly opposite. These objects cannot be well obtained when either the armature or the magnet are undergoing a rotary motion. In that case, when the position of the masses actuated by the opposite polarities, is most favourable for the exercise of their reciprocal attraction or repulsion, their position is least favourable for the production of circular motion. It is in

Fig. 80.



*M*, is established or nullified alternately, as the fly-wheel in revolving makes a communication with the coil of one or the other, by a mechanism called the *break piece*. The little cylindrical rod which forms the axis of the fly-wheel *W*, is filed away at two places of about a quarter of an inch in width, on opposite sides of the rod, leaving between them, a part which is not deprived of its rotundity. Of three springs proceeding vertically from beneath the base board, so as to be held firmly by it, one communicates by a wire beneath the board with the set screw on the right and through it with a pole of a battery. Pressing at the same time on the intermediate round portion of the axis, it keeps it constantly in the same electrical state as the pole of the battery with which it communicates. Each of the other two springs communicates through the wire of one of the helices *M*, with the left set screw, and through this with the other pole of the battery. The axis, as above mentioned, being in constant communication with one pole, the current alternately passes through the helix of one or the other electro-magnet, accordingly as the spring with which it communicates is, or is not, in contact with the axis in consequence of the alternate presentation at every semi-revolution of the portion which has been removed by the file or that which has been left in *statu quo*. As the portions in the last mentioned state, are on opposite sides, the contact of the springs with the axis, is alternate. Thus each magnet is alternately charged and alternately free. Consequently two keepers of soft iron associated with each other, and with a beam crank and fly-wheel, by being alternately attracted and liberated, undergo an alternate motion which is imparted to the beam. This motion by means of the crank causes the fly-wheel and its axis to revolve, and thus gives efficacy to the mechanism of the break piece.

It follows that the machine continues in motion as long as the galvanic current is applied.

The analogy between the mechanism of this apparatus, and that which is resorted to in steam engines, is self-evident.

the vicinity of the "dead point," so called technically, that there is the most intense reaction.

830. Davenport's apparatus did not differ essentially from that of Richie. In both, the alternation of polarity by which the beam was set in motion agreeably to the apparatus last described, was made to act upon an electro-magnet turning on a vertical axis between the jaws, either of a permanent magnet or of an electro-magnet. The former was employed by Richie, the latter by Davenport. I have been under the impression that Richie did not make due acknowledgment to Henry, for the hint afforded by the alternating beam engine. Yet De la Rive alleges that he saw an apparatus, in 1828, which had been contrived by Richie, to revolve by the alternation of polarity, resulting from changes in the direction of the galvanic current.\*

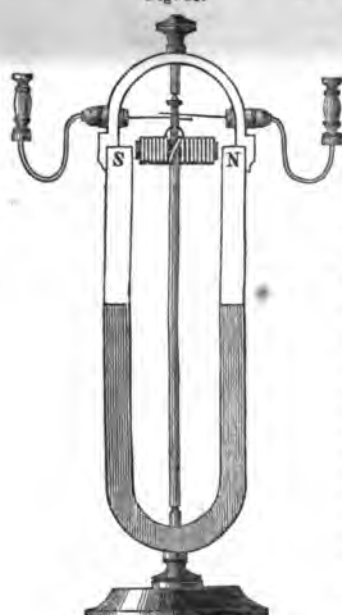
### *On the great Advantage of Electro-magnets as the Means of imparting Permanent Magnetism.*

831. One of the practical advantages arising from the art of making electro-magnets is, that we are enabled to impart instantaneously the most powerful magnetism to steel bars. The mode of employing for this purpose an electro-magnet, does not differ from that already described

#### *\* Richie's Revolving Electro-magnet.*

The following figure will give an idea of the apparatus which in Europe is known as Richie's revolving electro-magnet.

Fig. 81.

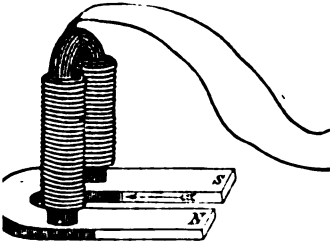


Two cups of mercury, or two set screws, are supported severally on each side of an arch of brass, by means of wires terminating each in one of the springs of a pole changer (767). By these means the helix in the electro-magnet is subjected to a current from a battery, of which the direction is reversed so often as the electro-magnet accomplishes a semi-revolution. If, while subjected to the current the electro-magnet be made to turn through a quadrant, so as to be at right angles to the position in which it is represented, each of its poles will be attracted by one pole and repelled by the other pole of the U-magnet, between the legs of which it is placed. Hence, as soon as liberated, it will seek to arrange itself so as to obey the polar impulses afforded to. But in being thus impelled, it acquires a rotary force which carries it so far as to have the current reversed by the pole changer. It is now impelled to reverse its position, but at half a turn encounters a change of polarity from the same causes as at first. Thus a rotation ensues and endures so long as the current is supplied. I have seen the electro-magnet supported horizontally upon the vertical axis as represented in the preceding figure, revolve so rapidly, as to make a humming noise, as to assume the appearance of an obtuse sphere or turnip-shaped disk.



and using the permanent magnet for the same purpose (729). In either case, however, when the magnet to be charged is of the U form, the induction is more powerful if an electro-magnet having the same distance between the legs is employed. As the coil may be made loose enough to slip on and off (825), rods of iron in the U shape, may be provided so as to suit the various permanent magnets required.

Fig. 82.



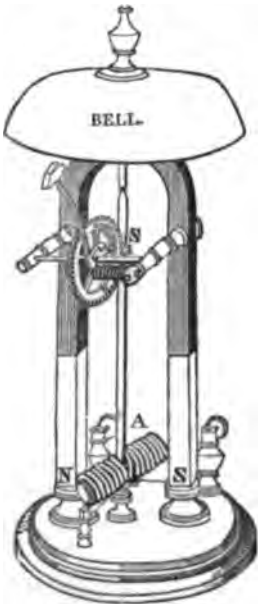
brought into the situation of a keeper, let the keeper be applied before the magnet is slid off.

832. Figure 82, will serve to illustrate the proper position of the electro-magnet relatively to a steel U bar to be magnetized, as when first applied. It is to be slid from the position in which it is represented, towards the ends of the steel U bar, two or three times; and finally being

#### *Dynamic Gold Leaf Galvanoscope.*

833. The figure of the gold leaf galvanoscope was introduced, in treating

Fig. 83.—Rotating Engine Bell.



of the galvanic circuit, in order to give the student an idea of the means which it affords of detecting a galvano-electrical current. The explanation of this instrument, requiring a reference to the laws and phenomena which fall under the head of reaction of magnets with electrical currents, was postponed in order to be given here, the figure being of necessity reinserted in the next page.

834. Between the legs of a U magnet, fig. 84, a glass tube is placed, to each end

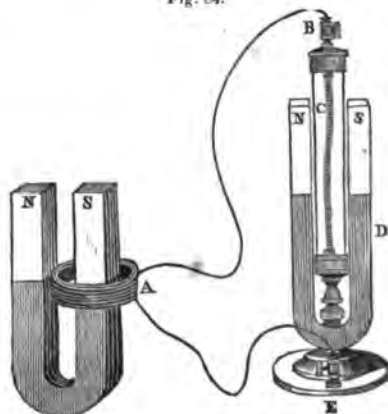
Figure 83, represents the revolving magnet, as associated with a bell, by means of a wheel-work, like that of a clock. An endless screw S, on the axis acts upon the teeth of a wheel, which as it revolves by means of a projecting pin, lifts the handle of a hammer until it arrives at a due elevation, where it is released from the pin. Then by the reaction of a spiral spring, the hammer is made to strike the bell. As the wheel has sixty-four teeth, it takes sixty-four revolutions of the magnet to cause one stroke. In some instances the number of strokes in a given time being ascertained, the revolutions were found to amount to more than one hundred in a second.

of which a brass cap is fitted, supporting within the tube forceps so affixed, as to be concentric with the axis of the tube. Between the forceps thus supported and another similar pair affixed to the lower cap of the tube, a strip of gold leaf is extended, of which one of the two ends is so held by each forceps, as to make it occupy the central space about the axis of the tube between the forceps. The caps communicate with set screws, to which wires are to be affixed, to complete any circuit, which is to be tried. When subjected to a very feeble galvanic discharge, the gold leaf will, agreeably to the law above stated (626), endeavour to quit the position which it holds, in order to take the tangential attitude, and while thus striving to escape from between the jaws of the magnet, inclines one way or the other, in a plane at right angles to one passing through the axes of both jaws (740).

*Of the Induction of Electrical Currents by Magnetism, or Magneto-electrical Induction.*

835. The influence of electric currents in inducing magnetism, having been fully demonstrated, the celebrated Faraday was led to inquire whether the converse might not be attainable. Accordingly he has ascertained, that electrical currents may be induced by magnetic action. As on the one hand, an electrical current circulating through a coil of wire will produce magnetism in an iron bar situated within the coil, so, on the other, if a bar previously magnetized be alternately introduced into the coil and withdrawn, currents will be induced in the coil at each ingress and egress of the bar. To the currents thus induced, as well as to those already described as resulting from the inductive influence of the current in one helix producing a current in another in its vicinity (781), the appellation of Faradian has been given in honour of their discoverer.

Fig. 84.



836. The inductive influence of a magnet, in causing an electrical current, may be illustrated by the process which the adjoining figure exemplifies. It will be perceived, that the gold leaf of the galvanoscope, already described (757), is made, as represented in the engraving, to complete the circuit of a coil of covered copper wire which has been so wound as to leave about its axis a v

cant space sufficient to receive either of the legs of a U magnet.

837. In putting the coil into the situation in which it is represented, the gold leaf will incline one way; on removing the coil, it will incline the other way: moreover, the flexure which arises on putting the coil on one leg, will be the opposite of that which will ensue when it may be put about the other leg. Yet removal from one leg, and placing it about the other, will be productive of a similar flexure. While the coil is stationary, the gold leaf is not affected. It is only during the changes of its situation relatively to the magnet, that any electric impulse is given adequate to the production of a transient current (633).

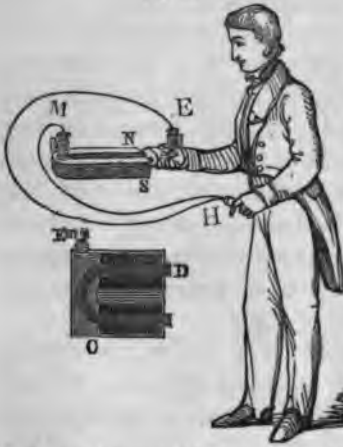
838. It has been pointed out that each end of the keeper of a magnet assumes a magnetic polarity opposite to that of the pole with which it may be in contact, but that the magnetism thus acquired, ceases on the removal of the keeper from the magnet. If we suppose such a keeper to be surrounded by a coil of insulated wire, we have only to remove it from its appropriate position, and restore it alternately, in order to produce a Faradian current within the coil at each change of position (835).

839. Under these circumstances, the magnetism of the keeper is destroyed as often as it is removed from the poles, and restored as often as it resumes its appropriate position; and an alternate accumulation and subsidence of the magnetic fluid within the keeper, is supposed to produce Faradian currents by its reaction with the electric matter in the wire.

840. The current produced by this last mentioned process was detected by Faraday, by causing the ends of the wire coiled about the keeper to communicate with the terminations of the coil of a multiplier, at the moment of removal from the poles of a powerful magnet. But of the current thus detected, indications were soon after obtained by the production of sparks. This interesting result was first attained by the distinguished Italian electricians, Nobili and Antinori, by causing the ends of the wire coiled about the keeper to break contact with each other through the medium of an amalgamated surface, in consequence of the jar arising from the lifting of the keeper from the poles of a magnet. Professor Forbes, of Edinburgh, produced

the same phenomenon shortly afterwards, by employing the same process with a powerful loadstone.

Fig. 85.



841. This experiment is illustrated by the adjoining figure. The armature is a U bar of soft iron, and is surrounded by a fine wire coil of great length. It may, advantageously, be fifteen hundred feet long. Of course it has its customary covering of cotton or silk. A section of it, and its case, is represented at E, O, D. One end of the wire is soldered to the armature and the case. The other end of the wire is soldered to the set screw, E, insulated from the case by ivory. H, held by the operator, is a metallic handle with two wires; one is attached to the set screw, E, and thus communicates with one end of the coil; the other communicates with the coil through the set screw, M, communicating with the magnet, and of course with the

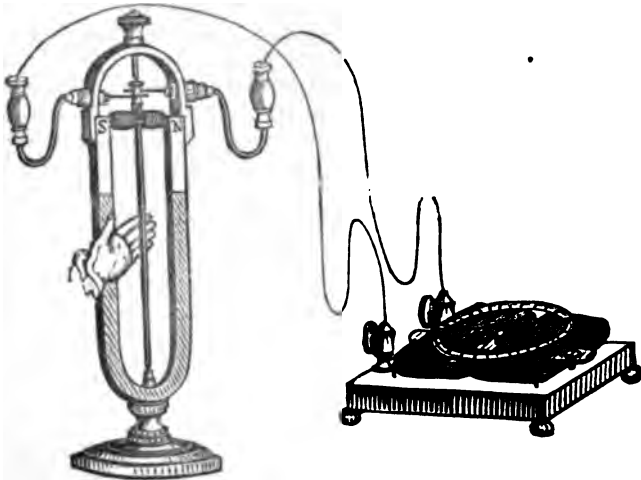
keeper, whenever it is in contact with the poles of the magnet. When the keeper is applied to the magnetic poles, it becomes a magnet (733); when separated, it returns to its previous state. The internal change which the keeper undergoes in acquiring or losing polarity, is productive, by induction, of contemporaneous currents in the coil. The resiliency of the polarized matter in the keeper, when it is suddenly put on, or pulled off from, the poles of the magnet, acts like that of a galvanic circuit when suddenly opened or closed (775). Hence, simultaneously with the removal, a sensation and a spark is perceived by the operator, who, when the circuit through the magnet is suspended, becomes the only medium through which the resilient secondary current (779) can pass. The current passes from the case to the right hand, and through his left, and the wire to the other end of the coil.

842. The changes of the relative situation of the keeper and magnet, by which the current within the coiled wire is excited, and arrested and reversed alternately, were much facilitated by a mechanism contrived by Pixii, of Paris, which caused the rapid rotation of a magnet near to a keeper, surrounded by a coil of wire. But, by Saxton, an obviously advantageous improvement was made, in causing the keeper to revolve instead of the magnet.

843. In consequence of the greater rapidity with which the reversal of the positions of the keeper could be accomplished by the aid of bands and multiplying wheels, the magneto-electric machine thus contrived by Pixii and improved by Saxton, not only produces deflections in the needle, as a succession of sparks which seem to have no intermission, but likewise severe shocks, the ignition of wire, and chemical decomposition.

844. If Richie's revolving electro-magnet, as modified by Page (81), be connected with a galvanometer, as represented in the adjoining figure, so causing the axis and electro-magnet which it supports to rotate, at every semi-revolution in the needle will be observed a deviation, which will alternately be opposite in direction.

Fig. 86.

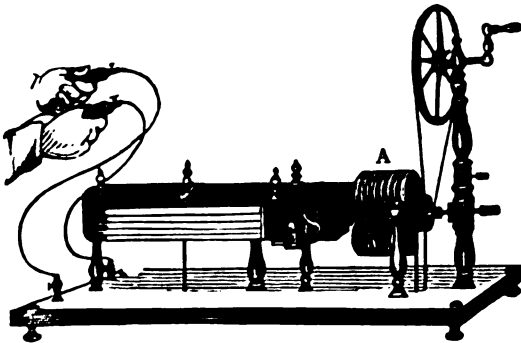


845. This phenomenon is perfectly analogous to that to which attention is in the next place to be given, in which a current is produced at every alternation of polarity of an iron keeper, consequent to the reversal of situation relatively to a permanent magnet.

*Of the Magneto-electric Machine.*

846. The following figure represents Saxton's magneto-electric machine, as well constructed by Daniel Davis, jr., of Boston.

Fig. 87.



847. A, represents the armature of this apparatus, supported on an axis, so as to be as near as possible to the terminating surfaces of the legs of a compound magnet. Of this axis one end reaches between the legs parallel to and equidistant from them, to a socket in the arched part. The other end of the axis, furnished with a pulley, terminates in another socket beyond the armature; so that, by means of a wheel and band, it may be made to revolve with great celerity.

848. The iron of the armature forms three sides of a rectangle. On the two opposite sides, 2500 feet of copper wire, of a grain to the inch in

weight, are wound so as to involve each side of the rectangular keeper in a coil.

849. It has already been explained, that an armature becomes a magnet by induction, so long as it is applied to its magnet; but that its polarity ceases when it is removed, or may be induced in the opposite way by the reversal of its position relatively to the magnet (733).

850. Now these changes all ensue during every semi-revolution, and during the shifting of the polarities a corresponding change is induced in the surrounding coil, equivalent to what is called an electrical current. The coils, when their ends are in communication, have produced with them alternate circuitous discharges, having all the attributes of those which occur within the active galvanic circuit.

851. The process is the converse of that which takes place in Richi's revolving electro-magnet, fig. 81. In that apparatus, alternations of opposite magnetic polarities are produced by alternations in the direction of an electrical current; in the magneto-electric machine, alternations of opposite electrical currents are produced by alternations of opposite magnetic polarities. This must be evident from the preceding illustration (829).

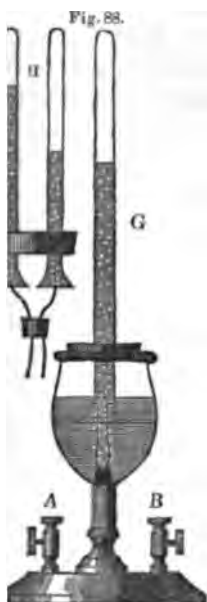
852. To obtain shocks from this machine, a toothed wheel attached to the axis, is connected with one of the extremities of the wire surrounding the keeper, the other end of this wire communicates with one of the set screws of the board, a spring of metal attached to an upright column of brass, plays upon the teeth of the revolving toothed wheel, and communicates with the other set screw. Any portion of the animal frame, being made to complete the circuit between the set screws, will receive a shock, arising from a resilient current, at each interruption of the circuit caused by the intermission of contact between the spring and teeth, as it leaps from one tooth to the other.

853. When cylinders of copper, soldered to the ends of the coil surrounding the keeper of a powerful magneto-electrical machine, are grasped firmly with the hands previously moistened, the most powerful man is unable during the action of the machine to relax his hold, he is placed at the mercy of the operator controlling the wheel of the machine.

854. Experience has shown that, for the production of the shock, the wire coiled about the keeper should be of comparatively great length, say fifteen hundred feet, but for producing ignition, should be much stouter, and not more than eighty feet in length. The propriety of making this difference of length, Mr. Saxton assures me, was first suggested by him.

855. Mr. Clark, of Adgar street, near the Adelaide Gallery, London, applies the keeper to the magnet on one side, near the ends of the legs, so that in his electro-magnetic machine the magnet is vertical, whereas in Saxton's it is horizontal. A priori, this would seem to promise no advantage, and yet machines thus constructed have proved at least as powerful as the others. The only advantage which I can conceive of, as resulting from the arrangement, is, that the movement of the keeper is in a direction tending to confirm the polarity of the steel magnet.

856. The magneto-electric machine has been resorted to as a remedy for nervous, rheumatic, and paralytic affections; and at all events may be used as a *medicina mentis*, which probably will do no harm, even when it does no good. It has a great advantage over common electrical machines in being independent of the weather, and is preferable to voltaic apparatus in not requiring the use of corrosive liquids. The apparatus may be carried in a box, without detriment, by land, as well as by water.

*Magneto-electric Electrolysis.*

857. The process by which the decomposition or electrolyzation of water, is accomplished by the currents induced by a magneto-electric machine, may be understood from the annexed engraving. Two wires proceeding from their solderings to the set screws A and B, may be observed to reach vertically into the trumpet-shaped orifice of the tube G, which is situated over them, and which must be at the outset replete with water.

858. It has been mentioned that to obtain the intensity requisite to sever shocks, the circuit is abruptly broken by a toothed wheel, while otherwise it would continue until the keeper should be off of the magnet. But this secondary current is not sufficiently enduring to be competent for electrolysis. In this respect it resembles discharges of statical electricity. Moreover, the current could not alternate in direction, as this would render it impossible to obtain the different elements separately.

859. In order to cause the electricity to flow always in the same direction, a pole changer, like that already described, must be employed. For the same reason, a current otherwise uniform in its course, may by this pole changer be made to flow alternately in opposite ways, so where a current is alternately opposite, the pole changer may render it uniform in its course. The change in position of the silver segments which convey the currents to the set screws, to which the electrodes of the battery are affixed, and the change in the direction of the discharges taking place simultaneously at every semi-revolution, if a segment begin with the reception of a positive charge, it must receive the same at the end of a half turn, and of course the set screw with which it communicates and any conductors thereto attached. All this is equally true of the segment which receives at the outset a negative discharge.

860. To effect the collection of the elements of water separately, it is necessary to employ two tubes O, H, one of

the wires acting as electrodes, being introduced into it. In this case as in others, the ratio of the bulk of the hydrogen to the oxygen, will be indicated by the space relatively occupied by them. With a good machine, to evolve a cubic inch of a mixture of both gases, may require between five and ten minutes.

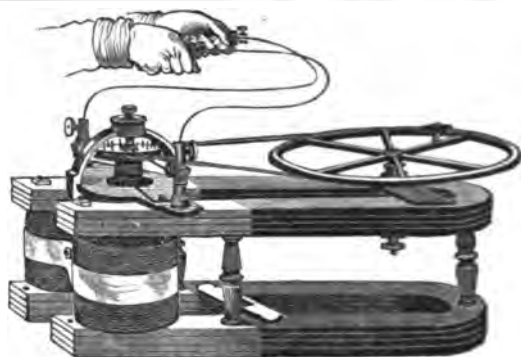


861. By the primary current of a magneto-electric machine, various saline solutions may be decomposed. For this purpose a tube in the shape of the letter U may be employed, figure 89. A pledget of cotton cloth may be made to occupy the bend, as a partition. The solution occupying each leg of the tube will give proof of its decomposition by appropriate tests. Any salt with a metallic radical which does not decompose water per se, will deposit metal on the negative electrode. Hence this process may be employed in gilding or silvering by electrolysis.

#### *Improved Magneto-electric Machine.*

862. Since the preceding descriptions were written, I have received from Mr. Davis, a magneto-electric machine, upon a construction which is entirely new, and of which the effects are very energetic.

Fig. 90.



863. It will be perceived, that in Saxton's machine, 80, the keeper is a soft iron bar so bent as to form three sides of a rectangle A, B, C, of which the two opposite sides B, C, may be designated as legs. Each leg is encircled by a helix of covered wire. The end of each leg is acted upon by one pole of a compound magnet, the side intermediate between the legs serves to act as a mean of communication between them, having no ability to bear the magneto-inductive influence.

864. But in the new instrument, a second compound magnet is used



Take the place of the inactive part of the rectangular keeper; so that two compound magnets are made to co-operate, to impart an opposite polarity by their application, at four extremities of two bars, instead of two extremities of one, equivalent to two, usually employed.

865. Of course each of the iron cylinders which takes the place of the legs of a rectangle in Saxton's construction, are presented to poles endowed with an opposite magnetic power. The north pole of the lower magnet is thus made to co-operate with the south pole of the upper one, and in like manner the south pole of the upper magnet with the north pole of the lower magnet, just as is the case when a keeper is in its appropriate place, each of its ends being in contact with one of the poles of the same magnet, the influence of these has a concurrent effect in producing an opposite polarity at the extremities of the keeper.

866. Respecting the efficacy of this machine, the following is the substance of a statement in a letter from my sagacious and much esteemed friend and pupil, Dr. W. F. Channing. The unmitigated shocks from this machine are insupportable. When the wires which break the shocks are removed, the current becomes sufficiently uniform to be competent for electrolysis or imparting magnetism to iron included in a long helix of fine wire comprised in the circuit of the helices of the machine. When sent through a circuit of a mile, the current from this machine, was found abundantly competent to work the telegraph of Professor Morse.

### *Of Ferro-dynamic Induction.*

867. I venture here to use an epithet for which I have no authority, so far as respects the employment of the Latin word for iron to designate the property of a mass of this metal to heighten the inductive influence of a coil by which it is magnetized, whenever the primary current is set in motion, and de-magnetized when this current is arrested.

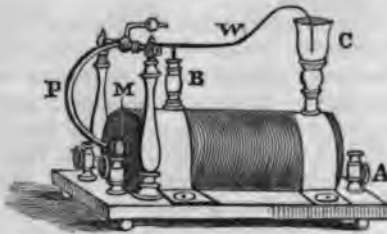
### *Of Callan's Faradian Apparatus, and Page's Callan and Faradian Electrotome.*

868. Instructed by the observations of Faraday above alluded to, Professor Callan constructed a very powerful apparatus, by surrounding an iron cylinder with two coils of covered wire, one within the other, the inner coil being coarse and short, the outer one long and slender. When the inner coil was made to form the circuit of a voltaic battery, the other was found to give severe shocks or brilliant sparks, at the moment of interrupting the circuit.

869. Dr. Charles Page has contrived several instruments upon the same Faradian principle. One of these is extremely interesting and ingenious, as it is so constructed as that the magnetic attraction of the included iron, arising from the influence of the circuit, attracts a lever from the position in which it forms a necessary portion of the circuit. The circuit is thus broken, but as the lever falls into its previous position, the circuit is renewed. Each time that the removal of the lever takes place, a shock is received by a person duly communicating with the terminations of the finer wire; and

a brilliant spark appears as often as the lever quits the surface of the mercury.

Fig. 91.



870. The apparatus, to, is represented by the ing figure 91. A coil of covered copper wire is about a bundle of straight iron wires like knitting. The helix thus constructed is surrounded by a helix of covered copper wire of one thousand feet, of whose ends are soldered to cop

screws inserted into the base board on the right. These set screws attaching severally one end of each of two wires, having a handle free end. One of the ends of the inner coil is attached to the set screw on the right, while the other end of this coil is soldered to a brass which secures the coil and supports the brass cup B, holding mercury. The cup C similarly occupied, is connected with another set screw corresponding to A, in size and situation. The wire W, which plays on a horizontal axis by means of a spur and its right hand termination, establishes conducting communication between the cups of mercury B and C, and is kept down by its own unresisted weight. It carries, however, a small iron at the left extremity, within half an inch of the bundle of coarse iron wires. As soon as the set screws on the right, which communicate with the coil, are made to receive the electrodes of a galvanic battery, the wire acquires an intense magnetic power, and attracting the iron at the left extremity, lifts the right end out of the mercury in the cup B. This breaks the circuit, to which the magnetic attraction of the coil and the weight of the wire beam no longer counteracted, causes it to fall back to its primitive situation. The magnetism is thus renewed, and the circuit is again interrupted, by the lifting of the end of the wire beam from the surfaces of the mercury in C. These alternations are accompanied with surprising rapidity, a brilliant spark being given as often as the contact with the mercury is broken. Meanwhile a person grasping the handles attached to the ends of the smaller coil, will receive a shock at the breach of the circuit, through the coarser coil. The shocks thus produced with an apparatus of a moderate strength and size, will be very severe.

871. Of the shocks resulting from the inductive power of one coil upon another, an account has been given. In that case, it seemed as if the effect of a larger coil upon a smaller one, is to cause a degree of electro-polarity commensurate with the weight and length of the inducing coil, but that in the discharge of this polarity, the intensity was inversely as the sectional area of the wire forming the coil.

872. But in the secondary current produced in Callan's apparatus, and Page's modification of it, which I have been describing, we have added the reaction of all the electro-polarity of the coil, an additional force to that of the magnetic polarity of the iron. The iron in the electro-magnetic coil undergoes the same magnetic change as that in the armature of the magneto-electric machine, although from a different cause. In the one case it *induces* a current, in the other it merely *promotes* a current, which exists independently of its aid.

*Decomposition aided by the Influence of the Resiliating Current of an Electrotome.*

873. M. De la Rive has devised an apparatus which he terms "Condensature Voltaïque." It comprises a small bar of iron, on which is closely wound thick copper wire, covered with silk. Through this wire the current of a single voltaic pair is made to circulate, while by means of a little electro-magnetic apparatus acting like Page's electrotome above described, the circuit of the current is broken and reversed. An apparatus for the decomposition of water being included in the circuit, it is found that the electrolytic effect of the voltaic pair employed is nearly doubled; while a bright light is afforded by interposed charcoal points. The voltaic condensor succeeds well only with a battery on which two electrolytes are used, as in those of Daniell, or Grove. For its success it is necessary that two chemical actions be going on at once within the voltaic pair employed with it. The wire wound around the bar should also be large in diameter, and of moderate length. The action of the apparatus is referred, by its inventor, to the depolarization of the platinum electrodes in the decomposing cell. Since its introduction into the circuit, however, produces precisely the same effect as would result from an addition to the number of pairs, a part at least of its efficacy must be referred to the efficiency of the iron as a reservoir of the polarity of which the resiliating discharge (775) takes place, with a velocity greater than that with which it is accumulated.

*Page's Apparatus for Regulating the Energy of the Resiliating Shocks of a Magneto-Electrotomic Apparatus.*

874. The great power of iron in increasing the capacity of a coil, upon Callan's construction, to give shocks, is beautifully illustrated by an apparatus made by Davies, under the direction of Doctor Page. Agreeably to the construction of this apparatus, two different coils, one of fine, the other of coarse wire of Callan's apparatus are separable. Figure 92, represents the instrument in question, as when the parts are duly associated. In figure 93, it appears as when the coils have been taken apart. The external helix, *a*, is formed of fine covered copper wire, not being less than one thousand feet in length. The ends of this coil are soldered severally to the set screws C, D. The inner coil consists of not less than three strands of coarse copper wire. The ends of these strands, which terminate in the same direction, are soldered all to the set screw A, on the base board. The other ends of the three strands are soldered to the serrated

Fig. 92.

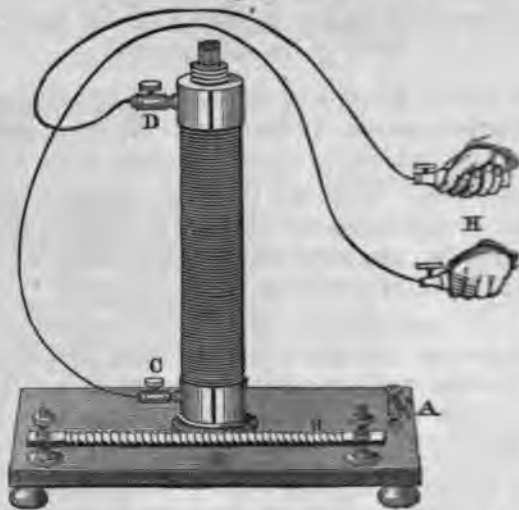
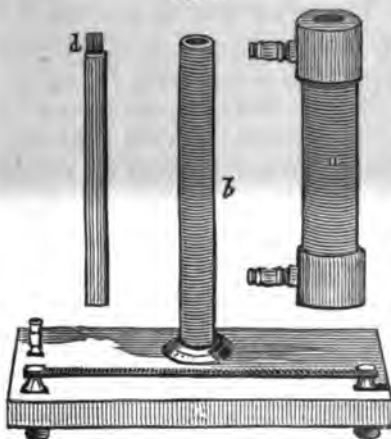


Fig. 93.



steel bar B: when these coils are situated one within the other, as in figure 92, on subjecting the inner coils to a galvanic current by attaching one of the electrodes to the set screw, the other electrode being in contact with B, on drawing the end of the wire, forming the electrode, over the teeth of the serrated bar, a brilliant spark will be seen as the wire leaps from one asperity to the other. If, during this process wires with metallic handles be attached severally at C and D, a person holding the handles will receive for every spark a perceptible shock. The addition of a single wire like a knitting needle will increase the shock sensibly, and by the further addition

of such wires the shock will be greatly increased, so that if the galvanic battery employed has only a square foot of zinc surface, the sensation becomes such as few are willing to bear. A rod of iron is not quite so efficacious as the bundle of wires of equal size. The inductive influence of the wires is not intercepted by their inclusion in a glass tube, but is much impaired by inclusion in a brass tube, in consequence of its diffusive power lowering the intensity. This is consistent with the experiments of Henry with flat coils (799). The brass tube, like the metallic sheets, interposes a closed and perfectly conducting circuit.\*

\* A more convenient form for the application of these shocks as a remedial agent is displayed by figure 115, by which the mode of operating is fully illustrated. The circuit with the battery is established by means of the wire reaching from the

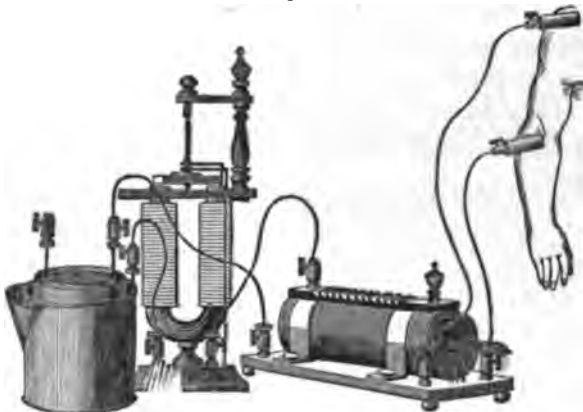
*Of Thermo-Electricity.*

875. When the needle of a galvanometer is deflected by the proximity of any body or set of bodies, of which different portions are of different temperatures, the phenomenon is ascribed to a thermo-electric current in contradistinction to those produced by galvanic apparatus. These have been distinguished by some electricians as hydro-electric currents, as in the necessity of water to their existence, they differ most pointedly from the currents above mentioned, which owe their activity to dry heat.

876. A thermo-electric current resembles a galvanic current of great quantity, but as to intensity extremely feeble. Other things being equal, a thermo-electric current flows from the hotter to the cooler portion of the mass. For the advantageous exhibition of this property, the bodies employed should have a great length in proportion to their other dimensions, as in wires or prisms. If the prisms of two heterogeneous metals have a conducting communication with each other between an extremity of each, while the other ends are in contact, or united by a slight soldering, on heating the ends associated as last

screw on the base board to one on the battery, while from the other on the battery, a wire proceeds through the coil of an electro-magnet to a set screw connected with the coarse inner coil of the electrotome.

Fig. 94.



The interruptions of the circuit are effected by an armature, which, by means of Page's pole changer (766), in revolving reverses at every half turn the direction of the current and the polarity of the electro-magnet, which causes its motion. Any part of the human body, the arm for instance, as represented in the figure, when completing the circuit of the outer coil, will be subjected to resisting shocks. Although, as these occur at every semi-revolution, the shocks are more numerous than when the serrated steel bar is employed, they are less severe.

mentioned, a current ensues from one metal to the other, through the juncture. The current flows always the same way, when the same metals are employed. The metal from which the current flows is said to be positive to the other. It should be called thermo-positive, and those which are relatively negative thermo-negative.

877. The reaction in this respect is of course consistent with that established in respect to metals employed in analogous galvanic processes. As the current in a galvanic triad is stronger in proportion as there is greater discordancy in the relation of the metals employed, so in thermometric apparatus there seems to be a series, in which each metal is positive as respects all that follow, and negative, as respects all that precede it. Heretofore bismuth was deemed the most thermo-positive, antimony the most thermo-negative of the metals, and hence, until lately, the most efficient thermo-electric batteries were made of bismuth and antimony. Recently, however, German silver has been found nearly as thermo-positive as bismuth, and is preferable from not being so exceedingly fusible. This fusibility limited the deflection of a needle, subjected to a current produced with a pile of bismuth and antimony, to  $82^{\circ}$ ; while German silver with antimony caused a deflection of  $88^{\circ}$ . German silver, however, while producing with antimony a deflection of  $88^{\circ}$ , produced under like circumstances a deflection of  $85^{\circ}$  with silver, brass, iron, palladium, copper or cadmium; being positive to all of them. With zinc it produced a deviation of  $84^{\circ}$ .

878. It has been shown by Nobili, that cylinders of clay partially baked, are capable of yielding thermo-electric currents.

879. As in the case of a galvanic circuit, a diversity, in the surfaces of the same metal or in the liquids to which it may be exposed, will enable it to act as two metals, and to give a current from one to the other; even partially twisting a wire, will cause the twisted portion to act as the negative metal, heat being applied at a certain distance from the twist.

880. In all cases where thermo-electric currents are concerned, no less than where those of galvanism prevail, the circuit must be completed in order to have a current.

881. It does not appear that there is any connexion between the thermo-electric, and galvano-electric relation of

metals, and those which exist between them as respects weight, specific gravity or conduction either of heat, or electricity. As heretofore combinations of antimony and bismuth were found most efficacious, the one being pre-eminently positive, the other pre-eminently negative, the idea arose that these metals might be indebted for this superiority to their eminently crystalline structure; but it has been found that German silver, with antimony, is more powerfully positive than bismuth is with that metal, although German silver is a malleable metal, of which the structure is not remarkably crystalline.

882. For the following table we are indebted to Cumming, one of the most distinguished among the cultivators of this branch of science.

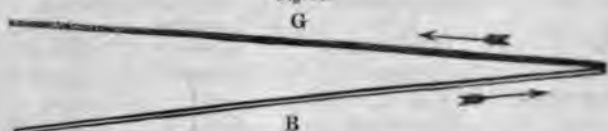
Thermo-electric series.	Hydro-electric series.	Series of conductors, of Electricity. of Heat.	
Galena	Potassium	Silver	Silver
Bismuth	Barium	Copper	Gold
German silver	Zinc	Lead	Tin
Mercury }	Cadmium	Gold }	Copper
Nickel }	Tin	Brass }	Platinum
Platinum	Iron	Zinc }	Iron
Palladium	Bismuth	Tin	Lead
Cobalt }	Antimony	Platinum	
Manganese }	Lead	Palladium	
Tin	Copper	Iron	
Lead	Silver		
Brass	Palladium		
Rhodium	Tellurium		
Gold	Gold		
Copper	Charcoal		
Silver	Platinum		
Zinc	Iridium		
Cadmium	Rhodium		
Charcoal }			
Plumbago }			
Antimony			

883. If to a platina wire which has been twisted about the middle, a flame be applied at some distance on one side of the twist, the ends of the wire being previously made to communicate through a galvanometer, the needle will indicate that a current flows from the heated part towards the twist. This is ascribed to the twisted part being cooler than the untwisted portion of the wire equidistant from the flame in consequence of a diminution of conducting power caused by the derangement of the metallic fibres during the torsion.

884. The needle will in like manner be affected, if a wire similarly communicating with a galvanometrical coil, be divided in the middle, then each end twisted, and one of the twisted ends, after being made red hot, brought into contact with the other. Similar results though feebler, may be obtained by means of copper and silver wire. That these effects do not depend on chemical reaction with the atmospheric oxygen, has been ascertained by their succeeding under pure oil.

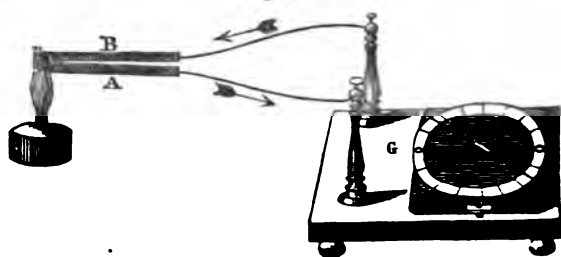
885. If one-half of a ring or rectangle, consisting either of bismuth or antimony, be heated, while the other half is kept cool by ice, a current will be excited sufficient to affect a needle, although no coil be employed to heighten its influence.

Fig. 95.



886. Let one end of a wire of German silver G, be brazed to one end of a brass wire B, on heating the juncture and making a communication between their other two ends by a third wire, a magnetic needle duly applied will be affected, as if a galvano-electric current of feeble intensity were circulating in the circuit thus formed. The deviation of the needle is such as to indicate that the thermo-electric current thus induced, flows from the wire of German silver to the brass wire.

Fig. 96.

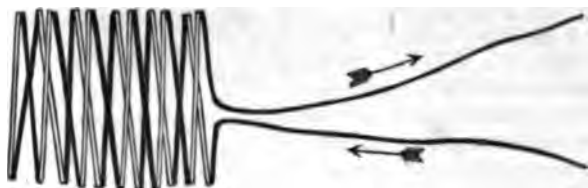


887. In the preceding figure, at B a bar of bismuth is represented, at A a bar of antimony, exactly alike as to dimensions. Each is represented as communicating, at one end, with one of the terminations of the wire of a galvanometer. Their other ends are, while touching, exposed to the flame of a lamp. Under these circumstances the needle of the galvanometer will be deflected. Of course the arrows indicate the current to take place, from the thermo-positive metal, to that which is comparatively thermo-negative.

888. Figure 97, represents a series of eleven pairs of German silver and brass wire, arranged in two rows, and soldered as above described in voltaic order. It is sufficient to heat or cool the junctures on either side to produce a current competent to deflect the needle of a galvanoscope, with



Fig. 97.



h it is made to communicate as represented by figure 96. Even the of the hand is sufficient to cause the needle exposed to the consequent ent to deviate to a perceptible extent.

*struction of a Thermo-electric Pile of Bismuth and Antimony, illustrated by an Engraving.*

39. Let any number of bars of bismuth and antimony, exactly similar l their dimensions, be bundled together, paper being interposed between lateral surfaces, so as to avoid metallic contact. Let the neighbouring of the heterogeneous bars thus associated be alternately soldered, and nately left free, so that any bar will have only one soldering at each and not be soldered at more than one end to any one bar. The order hich the bars must be united is exemplified in figure 97. The bars connected, will form one continuous metallic conductor, consisting nately of bismuth and antimony, so that on taking the whole into a gal- e circuit, all lateral discharge being prevented by the paper, the current ring by a bar of bismuth, would proceed through a bar of antimony, through a bar of bismuth, and so on coming out finally through a bar ntimony. The metals are in fact alternated like those of the couronne asses, excepting that the fluid, instead of being alternately conducted by il, alternately transmitted convectively through an interposed liquid, is eyed from bar to bar, wholly through the alternate metallic junctures.

30. The metals thus associated, exercise, when their alternate solderings at different temperatures, an electro-motive power due altogether to contact; so that the contact theory of Volta, however incompetent to unt for the powers of his pile, seems to be somewhat applicable in the case of the thermo-electric series. It is not pretended, that in the case he apparatus last mentioned, any chemical combination takes place, ss the successive passage of heat from particle to particle be considered arranting such an idea.

Fig. 98.



891. By figure 98, a thermo-electric battery is represented, consisting of sixty-three pairs of bars of bismuth and antimony, each three inches in length, three-fourths of an inch in breadth, and one-fourth of an inch in thickness, of course the bars are soldered to each other alternately, as above described, so as to be arranged in a series in voltaic order. They are insulated and secured by plaster of Paris, copper case, B, having above them, a space for receiving ice, and below her so situated as to be exposed to an appropriate cast iron plate, pre- sly heated to redness.

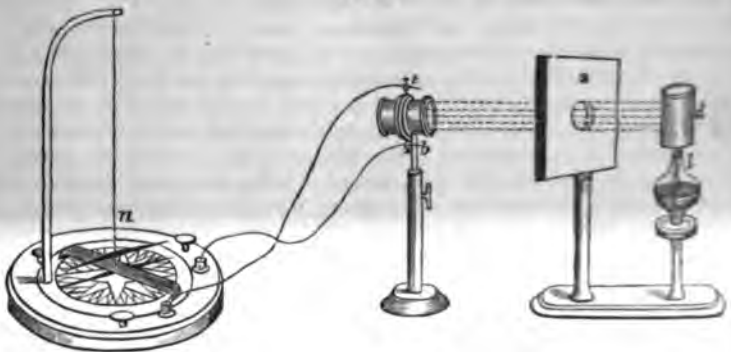
92. Two set screws for attaching wires are represented externally, each hich is made to communicate with one pole of the battery. The energy he current is in proportion to the difference of temperature, created in

those solderings of the bars, which are in the different surfaces of the bundle which they form collectively, by the application of heat at one surface, and cold at the other surface. Of course the greatest power results from applying ice or a cold mixture to the solderings at one of the surfaces, and at the other as much heat as bismuth will bear from a hot iron without fusion. A series thus constructed, caused the electro-magnet of Riche's apparatus to revolve rapidly. A serrated bar is attached to the front of the case, and is connected with one of the poles of the pile. When a wire, of which one end is affixed to a set screw soldered to the other pole, had its free end drawn over the teeth of the serrated bar, sparks were produced.

### *Of Melloni's Thermo-multiplier.*

893. By means of a thermo-electric series analogous to that illustrated by the preceding figure, associated with an extremely sensitive galvanometer, Melloni contrived a thermoscopic apparatus, more capable of detecting minute differences of temperature than any before known. It proved the means of making those interesting discoveries, of the difference in the permeability of bodies to the rays of heat and light, to which reference was made under the head of caloric (C, 309). It has been used to ascertain the temperature of insects and various parts of the animal system.

Fig. 99.



894. The series employed by Melloni, consisted of fifty pairs, about an inch and a fifth in length, and the whole forming a bundle of little over an inch in diameter. It was included in a cylindrical brass case, between which and the bars, no metallic contact was permitted. Wires proceeding from the extremities of the series were made to communicate with set screws *b, t*, insulated from the brass case by ivory.

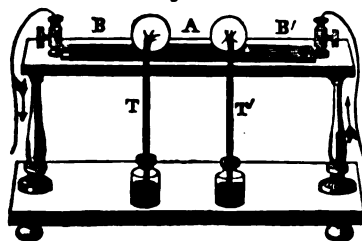
895. The mode in which this thermoscopic apparatus was employed, may be understood from the preceding figure. The heat of the copper cylinder *d*, received from the lamp *l*, reaches one side of the thermo-electric series through a hole in the screen *s*. The other not being exposed to the influence of any hot body. Under these circumstances a thermo-electric current is produced through the coil of the galvanometer, which by the attachment of its ends to the set screws *b, t*, is made to complete the circuit between the poles of the thermo-electric series.

896. It is inferred that the difference of temperature, created by the radiant heat reaching the surface of the series exposed thereto, will be as the quantity of electricity, and that as the deflections of the galvanometer measure the

electricity, they must also be an index of the degree of heat applied at the appropriate surface of the thermo-electric series. Melloni alleges, that this correspondence between the heat applied, and the deflections, has been ascertained to exist.\*

### *The Converse of the Thermo-electric Process.*

Fig. 100.



897. The object of figure 100, is to represent a thermo-electric apparatus, in which the phenomena are the inverse of those produced by the thermo-electric batteries, described in the preceding pages. In those a current of electricity is the consequence of a diversity of temperature; in the apparatus in question a diversity of temperature is the consequence of an electric current. The letter A, indicates a bar of antimony so situated between two bars of bismuth B, B, as to have its right end soldered to one, the left end to the other of these bars. Thus the three bars, form one metallic prism, uniform as to shape, though heterogeneous as to the materials, which rests horizontally upon a frame as represented in the figure. At each soldering a little concavity is made sufficient to hold a small quantity of water, and to receive the bulbs of the two air thermometers F and T. The water serves to facilitate the conduction of heat from the metal to the glass bulbs. The prism formed as described, of bismuth and antimony, being made the channel of a galvanic current, in the direction indicated by the arrows, from B through A to B, at the soldering of A to B, cold is produced and made evident by the thermometer T. Meanwhile on inspecting the other thermometer, it will be seen that heat is produced at the other soldering. By reversing the direction of the current, the effect on the thermometer will be reversed.

898. The extent of the elevation above the previous temperature is greater than the depression. This is ascribed to a small degree of heat, which the electric current causes, and which of course adds to the heat on one side, and lessens the cold on the other.

### *On Terrestrial Magnetism.*

899. The thermo-electric branch of science has a pre-eminent importance from the light which it has thrown

\* The following are the dimensions of the galvanometer or thermo-multiplier of Melloni and Nobili, associated with the thermoscopic apparatus as stated by Bequerel.

The wire is of copper doubly wound with silk, and of about three-hundredths of an inch in diameter. It makes 150 circumvolutions around a frame of about two inches square, and one-fourth of an inch in height. The needles are a little short of two inches in length.

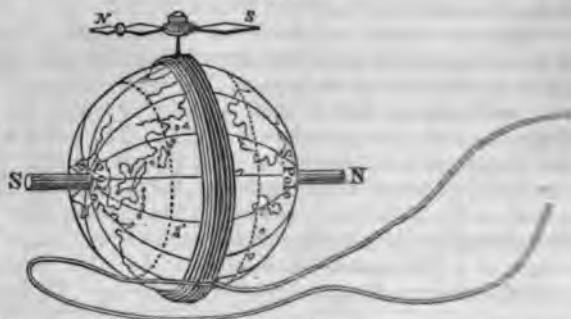
It will be perceived that there are two needles associated so as to form what is called an astatic needle. They are suspended by a single cocoon filament. In the apparatus as described by Bequerel, the cocoon is attached at the upper extremity to a swivel, as in the torsion electrometer of Coulomb, (E, 136,) and the frame may be made to rotate by means of a toothed wheel and pinion so as to adjust the needle to zero, of the graduated arch of ninety degrees, by which the deflections are measured. There is also a contrivance for lowering the needles so as to rest on the frame on which the wire is wound. When thus situated if it be desired to transport the instrument from one place to another, the needles are bound fast to the surface of the frame by a silk ribbon. The apparatus is included in a bell glass to protect it from being agitated by blasts of air, or soiled by dust.

on the nature and causes of the all-important polarity of the earth. This is now ascribed to the successive influence of the solar rays upon the temperature of the earth, causing a perpetual thermo-electric current from east to west.

900. It is by the reaction of its poles with this terrestrial thermo-electric current, which flows parallel to the equator, that the compass needle is made to arrange itself at right angles to that current, and thus to assume a direction nearly coincident with that of the meridian.

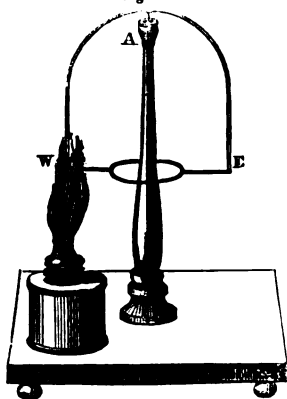
901. In the following figure, a coil of covered copper wire affords the means of causing an electrical current to circulate about a globe represent-

Fig. 101.



senting the earth. A magnetic needle is represented in the position in which it would arrange itself by reaction with the current in the coil.

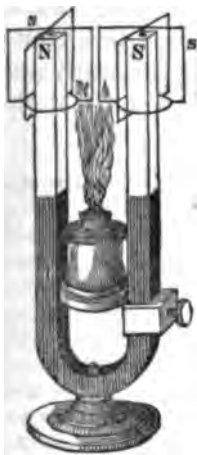
Fig. 102.



902. The apparatus represented by figure 101, serves to illustrate the reaction, with the magnetism of the earth, of a thermo-electric current, produced within an arch of brass wire soldered at its two ends to a ring of German silver. The arch is poised upon a pivot at the top of the pillar at A, which the ring encircles. The lamp, W, being situated as in the figure, the apparatus must be so placed, that a line passing through the centre of the flame to the top of the pillar, will be directed from west to east. Then, when the flame is applied to the juncture of the arched wire with the ring, a current will flow from the juncture, and of course from west to east through the arch. As the current will conflict with that of the earth, it will cause the wire to arrange itself, so as that this discordance may be avoided. But a semi-revolution bringing the extreme juncture of the arch and ring into the flame, a current through the arch from west to east is again induced, producing another semi-revolution. Of course this process will be repeated as long as the flame is applied.

903. Another illustration of the efficacy of thermo-electric currents, is afforded by their displaying an analogous reaction with a permanent steel magnet to that which has been shown to exist between such a magnet and the currents created by galvanism, in the experiment designated as that of Ampère's rotating battery (757).

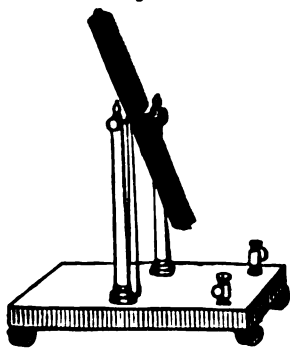
Fig. 103.



904. The frames of wire in the rectangular form, supported on the jaws of the permanent steel U magnet, as represented in the adjoining figure, may consist of silver in rings and platinum rectangles, or the rectangles may be of silver, and the rings of German silver. When the junctures of these frames are subjected to a flame as represented in the engraving, electric currents are made to flow in each from the heated juncture, through the silver wire, to the other juncture. The currents, thus incited, conflicting with the polar influence of the magnet, endeavour to arrange themselves so as to escape from conflict. But the only motion which the suspension will permit, is that of rotation, which, by bringing a juncture into the flame at every quarter revolution, causes the effort for a change of position to be repeated as often. Hence the frames revolve as long as the flame is applied.

#### *Electro-magnets revolving under the Influence of Terrestrial Thermo-electric Currents.*

Fig. 104.



has to the compass needle. represented by figure 104.

905. It has been shown, that an electro-magnet, situated on an axis, and subjected to the polar influence of another magnet, will strive to arrange itself so as to bring opposite poles into proximity; but that if the current to which it is indebted for its magnetism be, from the construction, liable to be reversed by a pole changer at every semi-revolution, a rotary motion will ensue. Two instruments have been constructed, in which terrestrial polarity is made to take the place of an artificial magnet, or an electrical current. One of these revolves in a horizontal plane, the other in a vertical plane; the latter having the same relation to the dipping needle that the former. The instrument which revolves vertically, is

#### *Of the Electro-magnetic Telegraph.*

906. Though the attempts which have been made to employ electro-magnetism, as a moving power, have hitherto failed, yet another important application of this agent has been made within a few years, in our own country, by

Prof. Morse, and in England by Messrs. Barrit and O and Prof. Wheatstone. With the telegraph of Mr. Morse, which has been the medium of communication between the cities of Baltimore and Washington, the public have become familiar. The apparatus thus employed, is superior in simplicity to any contrivance elsewhere proposed, of which any knowledge has reached this country. A description of his instrument, as now in operation within the Capitol at Washington, is all that I deem it expedient to introduce.

907. Upon a base board of wood, a U shaped bar of soft iron, with covered copper wire, is firmly attached in a vertical position. On the terminal wires of the electro-magnet thus formed, communicates the distant station by means of a wire, the other by means of the ground. A short distance above the electro-magnet, a bar or keeper of soft iron is attached at right angles to a lever. One extremity of this lever carries a steel point or tooth projecting downward, while through the other extremity is a pivot supported by two stanchions behind the electro-magnet. A spring is attached to the upper surface of the lever tending to raise this, and to keep the keeper, from the poles of the electro-magnet beneath. When the circuit is completed with the voltaic battery at the distant station, the electro-magnet being charged, and suddenly attracting the keeper, causes the lever to descend. Upon the rupture of the circuit, attraction ceases between the magnet and keeper, the spring causes the lever to rise again, and thus, by repeated completions and interruptions of the circuit, the lever may be made to play up and down, working upon the pivot as a fulcrum. Immediately beneath the steel point a cylinder of wood, covered with soft paper, is made to rotate upon an axis uniformly by means of clock work. When, by the completion of the circuit, the steel point is made to descend, it presses upon the soft paper of the revolving cylinder, and as long as the circuit remains unbroken. As the cylinder revolves, a dot or line of greater or less length is described upon the paper, and an arbitrary combination of such dots and lines constitutes the alphabet. Thus every letter may be written upon the paper at one extremity of a telegraphic wire of any length, by successive completions and interruptions of the circuit at the other.

908. As the velocity with which the electric current traverses a metal wire has been found by Mr. Wheatstone to be about 288,000 miles per second, it is obvious that no perceptible interval of time will elapse in the transmission of intelligence in this way, between any two points upon the earth's surface.

909. Various modes of establishing the wires between two stations have been devised. It was at first proposed to enclose two insulated wires within an iron pipe, buried beneath the surface of the earth; but this method is objectionable on the ground of expense, and liability to derangement. As above stated, Prof. Morse employs the earth itself for one-half of the circuit, and a wire, supported upon poles at some distance above the ground, as the other.

**AN EFFORT**

**TO**

**REFUTE THE ARGUMENTS ADVANCED**

**IN FAVOUR OF THE**

**EXISTENCE IN THE AMPHIDE SALTS, OF RADICALS,**

**CONSISTING,**

**LIKE CYANOGEN, OF MORE THAN ONE ELEMENT.**

**BY ROBERT HARE, M.D.**

**PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF PENNSYLVANIA.**

---

**PHILADELPHIA :**

**PRINTED BY JOHN C. CLARK, 60 DOCK STREET.**

**1842.**





## AN EFFORT

*To Refute the Arguments advanced in Favour of the Existence, in the Amphide Salts,\* of Radicals consisting, like Cyanogen, of more than one Element. By Robert Hare, M. D., Professor of Chemistry in the University of Pennsylvania.*

---

*The following is a Summary of the Opinions, which it is the Object of the subsequent Reasoning to Justify.*

(a) The community of effect, as respects the extrication of hydrogen by contact of certain metals with aqueous solutions of sulphuric and chlorohydric acid, is not an adequate ground for an inferred analogy of composition, since it must inevitably arise that any radical will, from any compound, displace any other radical, when the forces favouring its substitution preponderate over the quiescent affinities.

(b) But if, nevertheless, it be held that the evolution of hydrogen from any combination, by contact with a metal, is a sufficient proof of the existence of a halogen body, simple or compound, in the combination, the evolution of hydrogen from water, by the contact with any metal of the alkalis, must prove oxygen to be a halogen body; also the evolution of hydrogen from sulphydric, selenhydric, or tellurhydric acids, by similar means, would justify an inference that sulphur, selenium, or tellurium, as well as oxygen, belong to the halogen or salt radical class:—

(c) The amphigen bodies being thus proved to belong to the halogen class, oxides, sulphides, selenides, and tellurides, would be haloid salts, and their compounds double salts, instead of consisting of a compound radical and a metal:—

(d) The argument in favour of similarity of composition in the haloid and amphide salts, founded on a limited resemblance of properties in some instances, is more than counterbalanced by the extreme dissimilitude in many others:—

(e) As, in either class, almost every property may be found which is observed in any chemical compound, the existence of a similitude, in some cases, might be naturally expected:—

\* An amphide salt is one consisting of an acid and a base, each containing an amphigen body, either oxygen, sulphur, selenium, or tellurium, as its electro-negative ingredient.

† The epithet halogen is applied to bodies whose binary compounds with metals are deemed salts, and which are consequently called haloid salts.

(*f*) As it is evident that many salts, perfectly analogous in position, are extremely dissimilar in properties, it is not reasonable to consider resemblance in properties, as a proof of analogous composition:—

(*g*) No line of distinction, as respects either properties or position, can be drawn between the binary compounds of sulphur and phlogiston and halogen bodies, which justifies that separate classification which the doctrine requires; so that it must be untenable to apply the one, or be extended to the other:—

(*h*) The great diversity, both as respects properties and position of the bodies called salts, rendering it impossible to retain the meaning of the word, any attempt to vary the language of the theory of Chemistry, in reference to the idea of a salt, must be extremely pernicious:—

(*i*) There is at least as much mystery in the fact, that the addition of an atom of oxygen to an oxacid, should confer an affinity for a simple radical, as that the addition of an atom of this element to such a radical, should create an affinity between it and an oxide:—

(*j*) If one atom of oxygen confer upon the base into which it enters, the power to combine with one atom of acid, it is quite inconsistent that the affinity should be augmented, proportionably to the further accession of oxygen:—

(*k*) It were quite as anomalous, mysterious, and impossible, that there should be three oxyphosphoric acids, severally requiring saturation one, two, and three atoms of hydrogen, as that the three mercuric states of phosphoric acid should exist, requiring as many different equivalents of basic water:—

(*l*) The attributes of acidity alleged to be due altogether to the presence of basic water, are not seen in hydrated acids, when the water is in that form only; nor in such as are, like the oils, incapable of uniting with water as a solvent. Further, these attributes are admitted to belong to salts which, not holding water as a base, cannot be hydrurets or hydracids of any salt radical; while such attributes are found in compounds which, like carbonic or carbonic acid, cannot be considered as hydrurets, they do not exist in all that merit this appellation, as is evident in the case of prussic acid, or oil of bitter almonds:—

(*m*) It seems to have escaped attention, that if  $\text{SO}^4$  be the sulphurion of sulphates,  $\text{SO}^3$ , anhydrous sulphuric acid, must be the oxysulphurion of the sulphites; and that there must, in the hyposulphites and hyposulphates, be two other oxysulphurions!—

(*n*) The electrolytic experiments of Daniell have been

iously interpreted, since the electrolysis of the base of sulphate of soda would so cause the separation of sodium, and oxygen, that the oxygen would be attracted to the anode, the hydrogen and soda being *indirectly* evolved by the reaction of sodium with water; while the acid, deprived of its alkaline base, would be found at the anode in combination with basic water, without having been made to act in the capacity of an anion.

(o) The copper in the case of a solution of the sulphate of this metal and a solution of potash, separated by a membrane, would, by electrolyzation, be evolved by the same process as sodium, so long as there should be copper to perform the office of a cathion; and when there should no longer be any copper to act in this capacity, the metal of the alkali, or hydrogen of water, on the other side of the membrane, would act as a cathion; the oxygen acting as an anion from one electrode to the other, first to the copper, and then to the potassium:—

(p) The allegation that the copper was deposited from the want of an anion (oxysulphion) to combine with, is manifestly an error, since, had there been no anion, there could have been no discharge, as alleged, to hydrogen as a cathion, nor any electrolysis:—

(q) The hydrated oxide precipitated on the membrane came from the reaction of the alkali with the sulphate of copper; the precipitated oxide of this metal from the oxygen of the soda acting as an anion; and the deposit of metallic copper from the solutions performing, feebly, the part of electrodes, while themselves the subjects of electrolyzation:—

(r) The so called principles of Liebig,\* by which his theory of organic acids is preceded, are mainly an inversion of the truth, since they make the capacity of saturation of hydrated acids dependent on the quantity of hydrogen in their basic water, instead of making both the quantity of water, and, of course, the quantity of hydrogen therein, depend on their capacity:—

(s) All that is truly said of hydrogen would be equally true of any other radical, while the language employed would lead the student to suppose that there is a peculiar association between capacity of saturation, and presence of hydrogen.

\* *Traité de Chymie Organique*, tom. 1, page 7.



## AN EFFORT,

&c. &c.

---

1. Some of the most distinguished European chemists, encouraged by the number of instances in which the existence of hypothetical radicals has been rendered probable, have lately inferred the existence of a large number of such radicals in a most important class of bodies heretofore considered as compounds of acids and bases. It has been inferred, for instance, that sulphur, with four atoms of oxygen ( $\text{SO}^4$ ) constitutes a compound radical, which performs in hydrous sulphuric acid, the same part as chlorine in chlorohydric acid.

2. Graham has proposed sulphatoxygen as a name for this radical, and sulphatoxide for any of its compounds. Daniell has proposed oxysulphion and oxysulphionide for the same purposes. I have given the preference to a nomenclature moulded upon the last mentioned plan. In reasoning on the subject I shall use this nomenclature, not, however, with a view to sanction it, as I disapprove altogether of this innovation, and deny the sufficiency of the grounds upon which it has been justified. Consistently with the language suggested by Daniell, hydrous sulphuric acid, constituted of one atom of acid and one of basic water, ( $\text{SO}^4 + \text{HO}$ ) is a compound of oxysulphion and hydrogen ( $\text{SO}^4 + \text{H}$ ). Nitric acid ( $\text{NO}^5 + \text{HO}$ ) is a compound of oxynitron and hydrogen ( $\text{NO}^5 + \text{H}$ ). In like manner we should have oxyphosphion in phosphoric acid, oxyarsenion in arsenic acid, and in all acids, hitherto called hydrated, whether organic or inorganic, we should have radicals designated by names made after the same plan. Their salts having corresponding appellations, would be oxysulphionides, oxynitronides, &c. Also, in any salt in which any other of the amphigen class of Berzelius is the electro-negative ingredient, whether sulphur, selenium, or tellurium, all the ingredients excepting the electro-positive radical, would be considered as constituting a compound electronegative radical.\*

\* The conception of the existence of salt radicals seems to have originated with Davy. It was suggested by Berzelius, in his letter in reply to some strictures which I published on his Nomenclature, in the following language:—

“If, for instance, the true electro-chemical composition of the sulphate of potash should not be  $\text{KO} + \text{SO}^3$ , as is generally supposed, but  $\text{K} + \text{SO}^4$ , and it appears very natural that atoms, so eminently electro-negative as sulphur and oxygen, should be associated, we have, in the salt in question, potassium combined with a compound body, which, like cyanogen in  $\text{K} + \text{C}^3\text{N}$ , imitates simple halogen bodies, and gives a salt with potassium and other metals. The hydrated oxacids, agreeably to this view, would be then hydracids of a compound halogen body, from which metals may displace hydrogen, as in the hydracids of simple halogen bodies. Thus we know that  $\text{SO}^3$ , that is to say, anhydrous sulphuric acid, is a body, whose properties, as respects acidity, differ from those which we should expect in the active principle of hydrous sulphuric acid.

“The difference between the oxy-salts and the halo-salts is very easily illustrated

3. It may be expedient to take this opportunity of mentioning, that to advocates of this new view, disadvantageously, as I think, employ the word radical, to designate the electro-negative, as well as the electro-positive ingredient. Agreeably to the nomenclature of Berzelius, the former would be a compound halogen body. Cyanogen being analogous, is by him placed in the halogen class. I shall, therefore, in speaking of "salt radicals," improperly so called, employ the appellation contrived by the great Swedish chemist.

4. It seems, however, to be conceded, that however plausible may be the reasons for inferring the existence of halogen bodies in the amphigen class, it would be inexpedient to make a corresponding change in nomenclature on account of the great inconvenience which must arise from the consequent change of names.

5. Under these circumstances, it may be well to consider how far there is any necessity for adopting hypothetical views, to which it would be disadvantageous to accommodate the received language of chemistry. In the strictures on the Berzelian nomenclature, which drew from Berzelius the suggestions contained in the quotation at the foot of the preceding page, I stated it to be my impression that water should be considered as acting in some cases as an oxybase, in others as an oxacid; and, in examination of his reply,\* I observed that *hydrous sulphuric acid might be considered as a sulphate of hydrogen, and that when this acid reacts with zinc or iron, the proneness of hydrogen to the æriform state enables either metal to take its place, agreeably to the established laws of affinity.*

6. There appears to have been a coincidence of opinion between Kane, Graham, Gregory, and myself, as respects the electro-positive relation of hydrogen to the amphigen and halogen elements, which I have designated collectively as the basacigen class; also in the impression that hydrogen acts like a metallic radical, its oxide, water, performing the part of a base. I agree perfectly with Gregory in considering that hydrated acids may be considered as "hydrogen salts." But when the learned chemist alleges that "*acids and salts, as respects their constitution, will form a class,*" I consider him, and those who sanction this allegation, to be committing an error upon an oversight. Because the salts of hydrogen, or rather, have water for their base, have heretofore been erroneously called acids; we are henceforth to confound salts with acids, and, instead of creating one wrong name, cause all others to conform thereto!

7. I fully concur with Gregory and Kane, in considering that water, hydrous sulphuric acid, in nitric acid, chloric acid, and in oxygen gas, generally acts as a base; also, that in this basic water hydrogen performs a part perfectly analogous to that of a metallic radical; but, agreeably

by formulæ. In KFF (fluoride of potassium), there is but one single line of substitution, that is to say, that of K|FF; whilst in KOOOOS (sulphate of potash) there are two, K|OOOOS and KO|OOOOS, of which we use the first in replacing one metal by another, for instance, copper by iron; and the second in replacing one oxide by another.

"I do not know what value you may attach to this development of the constitution of the oxy-salts (which applies equally to the sulpho-salts and others); but myself, I have a thorough conviction that there is therein something more than a vague speculation, since it unfolds to us an internal analogy in phenomena which agreeably to the perception of our senses, are extremely analogous.

Silliman's Journal, Vol. 27, for 1835, page 61.

his view, I cannot perceive any difficulty in accounting for the evolution of hydrogen, as suggested in the quotation above made (6), agreeably to which, when diluted sulphuric acid reacts with zinc or iron, the liberation of hydrogen results from the superiority of the forces which tend to insert either of these metals in the place occupied by the hydrogen, over those which tend to retain it in statu quo.

8. When oxide of copper is presented to chlorohydric acid, it is inferred that the hydrogen unites with oxygen, and the chlorine with the metal; and hence it seems to be presumed, that when oxide of copper is combined with sulphuric acid, a similar play of affinities should ensue: but would it be reasonable to make this a ground for assuming the existence of a compound radical, when the phenomena admit of another explanation quite as simple and consistent with the laws of chemical affinity?

9. Whether hydrogen be replaced by zinc, or oxide of hydrogen by oxide of copper, cannot make any material difference. In the one case, a radical expels another radical, and takes its place; in the other, a base expels another base, and takes its place.

10. There can be no difficulty, then, in understanding wherefore, from the compound of sulphur and three atoms of oxygen, and an atom of basic water, hydrogen should be expelled and replaced by zinc, or that water should be expelled and replaced by oxide of copper; the only mystery is in the fact, that  $\text{SO}^3$ , as anhydrous sulphuric acid, will not combine with hydrogen, copper, or any other radical, unless oxydized. But this mystery equally exists on assuming that an additional atom of oxygen converts  $\text{SO}^3$  into oxysulphion, endowed with an energetic affinity for metallic radicals, to which  $\text{SO}^3$  is quite indifferent.

11. In either case an inexplicable mystery exists; but it is, in the one case, associated with an hypothetical change, in the other, with one which is known to take place.

12. But if hydrous sulphuric acid is to be assumed to be a hydruret of a compound halogen body (*oxysulphion*), because it evolves hydrogen on contact with zinc, wherefore is not water, which evolves hydrogen on contact with potassium, sodium, barium, strontium, or calcium, to be considered as a hydruret of oxygen, making oxygen a halogen body?

13. Boldly begging the question, Graham reasons thus: "*the chlorides themselves being salts, their compounds must be double salts.*"

14. But if the chlorides are salts, the chloride of hydrogen is a salt; and if so, wherefore is not the oxide of hydrogen a salt, which, in its susceptibility of the crystalline form, has a salt attribute which the æriform chloride does not possess?

15. Further, if the oxide of hydrogen be a salt, every oxide is a salt, as well as every chloride. Now, controverting the argument above quoted, by analogous reasoning, it may be said, "*the oxides themselves being salts, their compounds are double salts.*" Of course sulphate of potash is not a sulphatoxide, as Graham's ingenious nomenclature would make it, but must be a double salt, since it consists of two oxides in "themselves salts."

16. I trust that sufficient reasons have been adduced, to make it evident that the common result of the extrication of hydrogen, during the reaction of zinc or iron with sulphuric or chlorohydric acid, is not a competent ground for assuming that there are, in amphide salts, "compound radicals" playing the same part as halogen bodies.

17. Let us, in the next place, consider the argument in favour of the ex-

istence of such radicals, founded on the similitude of the haloid and amphide salts, which is stated by Dr. Kane in the following words:—

“It had long been remarked as curious, that bodies so different in position as the compound of chlorine with a metal, on one hand, and an oxygen acid with the oxide of the metal on the other, should be so similar in properties that both must be classed as salts, and should give rise to series of basic and acid compounds for the most part completely parallel.” *Elements*, p. 681.

18. Upon the *similitude and complete parallelism* of the amphide and haloid salts, thus erroneously alleged, the author proceeds to argue in favour of the existence in the former, of compound halogen bodies, arising in their mode of combination to chlorine or iodine.

19. I presume it will be granted, that if similitude in properties be a sufficient ground for inferring an analogy in composition, dissimilitude is to justify an opposite inference. And that if, as the author alleges, compound bodies have been classed as salts, on account of their similarity in this respect, when dissimilar they ought not to be so classed. Under this view of the question, I propose to examine how far any similitude in properties exists between the bodies designated as salts by the author or any other chemist.

20. The salts, hitherto considered as compounds of acids and bases, by Berzelius called amphide salts, being produced severally by the action of one or other of his amphigen class, comprising oxygen, sulphur, selenium, and tellurium, with two radicals, with one of which an acid is formed, with the other a base. The binary compounds of his halogen class comprising chlorine, bromine, iodine, fluorine and cyanogen, are called by him haloid salts. I shall use the names thus suggested.

21. Among the haloid salts we have common salt and Derbyshire salt, the gaseous fluorides and chlorides of hydrogen, silicon or boron; the volatile liquor of Libavius; the acrid butyraceous chlorides of zinc, bismuth, antimony; the volatile chlorides of magnesium, iron, chromium, and mercury, and the fixed chlorides of calcium, barium, strontium, silver, lead; the volatile poison prussic acid, and solid poisonous bichloride of mercury, with various inert cyanides like those of Prussian blue: likewise a great number of etherial compounds.

22. Among the amphide salts are the very soluble sulphates of iron, copper, soda, magnesia, &c., and the insoluble stony sulphates of strontia and strontia; also ceruse and sugar of lead; alabaster, marble, &c. ethers, and innumerable stony silicates, and aluminates. Last, but among the least discordant, are the hydrated acids, and alkaline and metallic hydrates.

23. When the various sets of bodies, above enumerated, as comprising the two classes under consideration, are contemplated, is it not evident that not only between several sets of haloid and amphide salts, but also between several sets in either class, there is an extreme discordancy in properties, so that making properties the test would involve not only that various bodies in one class could not be coupled with certain sets in the other, but, that in neither class could any one set be selected as exemplifying the characteristics of a salt, without depriving a majority of those similarly constituted, of all pretensions to the saline character?

24. Now, if among the bodies above enumerated, some pairs of amphide and haloid salts can be selected, which make a tolerable match with re-



their properties, as in the case of sulphate of soda, and chloride of sodium, while in other cases there is the greatest discordancy, (as in the stony silicate felspar, and the gaseous fluoride fluosilicic acid gas; as in soap and Derbyshire spar; as in marble and the fuming liquor of Libavius, the sour protochloride of tin, and sweet acetate of lead), is it reasonable to found an argument in favour of a hypothetical similitude in composition, on the *resemblance* of the two classes in properties? Does not the *extreme* dissimilitude in some cases, more than countervail the limited resemblance in others? And when the great variety of properties displayed both by the amphide and haloid salts is considered, is it a cause for wonder or perplexity, that in some instances, amphide salts should be found to resemble those of *no* other kind?

25. Again, admitting that there was any cause for perplexity agreeably to the old doctrine, is there less, agreeably to that which is now recommended? Is there no ground for wonder that oxygen or sulphur cannot act as simple halogen bodies? By what rule are their binary compounds to be excluded from the class of haloid salts? Wherefore should chlorides, bromides, iodides, and fluorides, however antisaline in their properties, be considered as salts, while in no case is an oxide, a sulphide, selenide or telluride to be deemed worthy of that name?

26. I challenge any chemist to assign any good reason wherefore the red oxide of mercury is any more a salt than the red oxide, or the protochloride is more saline than the sulphide: or why the volatile oxides of osmium or of arsenic are less saline than horn silver or horn lead; or the volatile chloride of arsenic, than the comparatively fixed sulphides of the same metal: why gaseous chlorohydric acid is more saline than steam or gaseous oxyhydric acid.

27. It much surprises me, that when so much stress is laid upon the idea of a salt, the impossibility of defining the meaning of the word escapes attention. How is a salt to be distinguished from any other binary compound? When the discordant group of substances which have been enumerated under this name is contemplated, is it not evident that no definition of them can be founded on community of properties; and, by the advocates of the new doctrine, composition has been made the object of definition, instead of being the basis; thus, agreeably to them, a compound is not a salt, because it is made of certain elements; but, on the contrary, an element, whether simple or compound, belongs to the class of salt radicals, because it produces a salt. Since sulphur, with four atoms of oxygen,  $\text{SO}_4$ , produces a salt with a metal, it must be deemed a salt radical.

28. In proof that the double chlorides are not united in a way to justify the opinion adopted by Bonsdorff, Thomson, myself, and others, it is alleged by Graham, "*that in such compounds the characters of the constituent salts are very little affected by their state of union.*"

29. This allegation being, in the next page, admitted to be inapplicable in the case of the double cyanides; an effort is made to get over this obstacle, by suggesting the existence of another compound radical. But the allegation of the author is erroneous as respects various double haloid salts, especially the fluosilicates, the fluoborates, fluozirconiates, the chloroplatinate, chloroiridiate, chloroosmiates, chloropalladiates, &c., all of them compounds in which the constituent fluorides and chlorides exist in a state of energetic combination by which they are materially altered as to their state of existence.

30. Evidently the word salt has been so used, or rather so abused, that

as a compound radical, consisting of hydrogen, hydroxion, and these compounds would conceive that the haloid compounds, erroneously more correctly considered as single salts, can be

32. Between the reaction of fluoboric acid with acid with oxybases, is there not a great resemblance

33. I am unable to understand how, if the oxy-salts is inferred, the other salts of the amphibol from a corresponding inference. But if the existence of double sulphides be admitted, can it be consistent also in double chlorides, iodides, &c.? Is there a difference between the habitudes of sulphur, selenium, and those of the halogen bodies?

34. Would not the modification of the etherial hypothesis, be disadvantageous, both in the reception of those compounds, and the names which are appropriate? Would not the transfer of the oxygen from the acid, and the creation, thus, of new salt radicals be objectionable; such as oxyoxalation for oxalates, oxyaceticion for acetates; while, for their compounds, oxalationides, oxytartarionides, oxyaceticionides, &c.

35. If sulphates are to be considered as oxy-salts, are we to designate the sulphites, hyposulphites,  $S^2 O^3$ ,  $S^3 O^3$ ?  $SO^3$  may, perhaps, with more propriety, consist of a compound radical,  $SO^2$ , and of sulphurous acid; but in a sulphite, anhydrous, is a species of oxy-sulphurion itself, being as much a sulphite, as  $SO^4$  is of the sulphates. Of course, infinity for radicals, contrary to fact. I presume to be trioxysulphionides; hyposulphites, sesquiquinoxysulphionides; while the hyposulphates, quinoxysulphionides!!!

36. Analogous complication in nomenclature for the nitrites and nitrates, phosphites and phosphates; also as respects the carbonic, and oxalic acids.

37. It is true that nature has not so made her elements separated into classes between which any distinction

creating the compounds formed by electro-negative elements with anions, as acids; those formed with cations, as bases; while the combinations formed by the union of such acids and bases have been considered as simple salts. Thus four classes are constituted, consisting of electro-negative elements, of acids, bases, and single salts, while, by the union of the latter, a fifth class of double salts is formed. Whether the words acid, base, and salt, be adhered to, objectionable as they are in some respects, and especially the latter, or some others be contrived, it would seem to me disadvantageous to merge them in one name, pursuant to the views of the advocates of salt radicals, as stated by Gregory in his edition of Turner's Chemistry, 572.

38. The objection, that not being electrolytes the relation of acids and bases to the voltaic electrodes cannot be discovered, is easily remedied; since, on the union of a common ingredient with an anion and a cation, there cannot be any doubt that the resulting compounds will have the same electro-chemical relation as their respective heterogeneous ingredients; so that, with the anion, an acid or electro-negative body will be formed; with the cation, a base or electro-positive body. Moreover, as respects organic compounds which cannot be subjected to the electrolytic test, whatever saturates an inorganic acid must be a base, and whatever saturates an inorganic base must be an acid.

39. The word salt, I have shown, is almost destitute of utility, from the impossibility of defining it, and the amplitude of its meaning. A word that means every thing, is nearly as useless as that which means nothing.

40. As respects the three phosphates of water,  $\text{PO}^3 + \text{HO}$ ,  $\text{PO}^3 + 2\text{HO}$ ,  $\text{PO}^3 + 3\text{HO}$ , the argument used by Dr. Kane cuts both ways; although, by its employer, only that edge is noticed which suits his own purpose. It is alleged that the difference of properties, in these phosphates, is totally inexplicable upon the idea of three degrees of "hydration;" but that all difficulty vanishes, when they are considered as three different compound salt radicals, oxyphosphonides of hydrogen,  $\text{PO}^3 + \text{H}$ ,  $\text{PO}^3 + 2\text{H}$ ,  $\text{PO}^3 + 3\text{H}$ .

41. To me the formation of three compound elements, by the reiterated addition of an atom, of which five of the same kind were previously in the mass to which the addition is made, seems more anomalous, mysterious, and improbable, than the existence of three compounds of phosphoric acid with water, in which the presence of the different proportions of water is the consequence of some change in the constitution of the elements which is referred to isomerism.

42. No reason can be given why the addition of *one, two, and three atoms of oxygen*, to the "radical," should convey a power to hold a proportional number of atoms of hydrogen. Such an acquisition of power is an anomaly.

43. In the case of radicals formed with hydrogen in different proportions, as in acetyl and ethyl, formyl and methyl, the number of atoms of oxygen in the peroxides, is the inverse of the hydrogen in the radical.

44. Ethyl,  $\text{C}^2, \text{H}^5$ , unites, at most, with one atom of oxygen, while acetylene,  $\text{C}^2, \text{H}^2$ , takes three atoms to form acetic acid,  $\text{C}^2, \text{H}^4, \text{O}^2$ . Methyl,  $\text{C}^1, \text{H}^3$ , forms, in like manner, only a protoxide, while formyl,  $\text{C}^1, \text{H}$ , takes three atoms to constitute formic acid.

45. Besides the three oxyphosphonides, of which the formulas are above stated, there would have to be another in the phosphites; so that instead of the hydrated acid, or phosphite of water, being  $\text{PO}^3 + \text{HO}$ , it would have to be  $\text{PO}^3 + \text{H}$ , a fourth oxyphosphonide of hydrogen.

46. Respecting the new principles which I have been contesting, Dr. Kane alleges "that the elegance and simplicity with which the law of saline combination may be traced from them is remarkable," because he conceives, that without an appeal to those principles, the fact that the number of equivalents of acid in a salt are proportionable to the number of equivalents of oxygen in the base, would be inexplicable.

47. Thus, when the base is a protoxide, we have one atom of the protoxide of hydrogen to take its place; when the base is a sesquioxide (two of radical and three of oxygen), three atoms of the protoxide of hydrogen take its place: if the base be a bioxide, two atoms of the protoxide of hydrogen take its place.

48. I have already adverted to the existence of certain chemical laws inexplicable in the present state of human knowledge. Among these is that of the necessity of oxidation to enable metallic radicals to combine with acids. But as a similar mystery exists as respects the adventitious property of combining with radicals, which results from the acquisition of an additional atom of oxygen by any of the compounds hitherto considered as anhydrous acids, the new doctrine has in that respect no pre-eminence claim to credence.

49. But if, without impairing the comparative pretensions of the prevailing doctrine, we may appeal to the fact that the acquisition of an atom of oxygen confers upon a radical the basic power to hold one atom of acid, is it not consistent that the acquisition of two atoms of oxygen should confer the power to hold two atoms of acid, and that with each further acquisition of oxygen a further power to hold acids should be conferred?

50. So far then there is in the old doctrine no more inscrutability than in that which has been proposed as its successor. Since if on the one hand it be requisite that for each atom of oxygen in the base, there shall be an atom of acid in any salt which it may form, on the other, in the case of the three oxyphosphons, for each additional atom of hydrogen extraneous to the salt radical, there must be an atom of oxygen superadded to this radical.

51. It being then admitted that, numerically, the atoms of oxygen in an oxysalt will be as the atoms of oxygen in the base, it must be evident that whenever an oxysalt of a protoxide is decomposed by a bioxide, there must have to be two atoms of the former for one of the latter. For example, if a salt has two atoms of oxygen, and requires by the premises two atoms of bioxide to decompose it, while the salt of the protoxide, having but one atom of oxygen, requires only one atom of bioxide, and yield, only one atom of acid. Two atoms of this salt, therefore, whether its base be water, or any other protoxide, will be decomposed by one atom of bioxide; provided the affinity of the acid for the bioxide is more potent over that entertained for the protoxide, as when water is the base.

52. It follows, that the displacement of water from its sulphate, as effected by Kane, does not favour the idea that hydrous sulphuric acid is a sulphionide of hydrogen, more than the impression that it is a sulphate of water.

53. Of course, in the case of presenting either a sesquioxide or a bioxide, to the last mentioned sulphate, in other words, hydrous sulphuric acid, the same rationale will be applicable.

54. The next argument advanced by Dr. Kane, is, that some of the acids of which the existence is assumed upon the old doctrine, are hypothetical, as they have never been isolated. This mode of reasoning may seem to react against the new doctrine with pre-eminent force, since all the

compound radicals imagined by it are *hypothetical*—none of them having been isolated.

55. The third argument of the respectable author above named is, that acids display their acid character in a high degree only when in the combination with water.

56. This argument should be considered in reference to two different cases, in one of which all the water held by the acid is in the state of a base, while in the other an additional quantity is present acting as a solvent. So far as water, *acting as a solvent*, facilitates the reaction between acids and bases, it performs a part in common with alcohol, ether, volatile oils, resins, vitrifiable fluxes, and caloric. Its efficacy must be referred to the general law, that fluidity is necessary to chemical reaction. "*Corpora non agunt nisi soluta.*"

57. In a majority of cases, basic water, unaided by an additional portion acting as a solvent, is quite incompetent to produce reaction between acids and other bodies. Neither between sulphuric acid and zinc, between nitric acid and silver, nor between glacial or crystallized acids and metallic oxides, does any reaction take place without the aid of water acting as a solvent, and performing a part analogous to that which heat performs in promoting the union of those oxybases with boric, or silicic acid.

58. It is only with *soluble* acids that water has any efficacy. The difference between the energy of sulphuric and silicic acid, under the different circumstances in which they can reciprocally displace each other, is founded on the nature of the solvents which they require, the one being only capable of liquefaction by water, the other by caloric.

59. In support of his opinions the author adverts to the fact, that with hydrated sulphuric acid, baryta will combine energetically *in the cold*, while a similar union between the anhydrous vapour and the same base cannot be accomplished *without heat*. But it ought to be recollected, that to make this argument good, it should be shown wherefore heat causes the baryta, a perfectly fixed body, to unite more readily with an æriform substance in which increase of temperature must, by rarefaction, diminish the number of its particles in contact with the solid. If the only answer be, that heat effects some mysterious changes in affinity, (or as I would say in the electrical state of the particles) it should be shown that the presence of water or any other base has not been productive of a similar change, before another explanation is held to be necessary. But I would also call to mind that the hydrated acid is presented in the liquid state; and if it be asked why water, having less affinity than baryta, can better cause the condensation of the acid, I reply, that it is brought into contact with the acid both as a liquid and a vapour, of neither of which forms is the earthy base susceptible. But if all that is necessary to convert anhydrous sulphuric acid into an oxysulphonide, be an atom of oxygen and an atom of metal, what is to prevent baryta and anhydrous sulphuric acid from forming an oxysulphonide of barium? All the elements are present which are necessary to form either a sulphate or oxysulphonide; and I am unable to conceive wherefore the inability to combine does not operate as much against the existence of radicals as of bases.

60. I would be glad to learn why, agreeably to the salt radical theory, anhydrous sulphuric acid unites with water more greedily than with baryta, and yet abandons the water promptly on being presented to this base. Why should it form an oxysulphonide with hydrogen more readily than with barium, and yet display, subsequently, a vastly superior affinity for barium?

61. It seems to be overlooked, that anhydrous sulphuric acid, by oxysulphion of the sulphites, ought to form *sulphites* on contact with

62. But if the sulphate of water owe its energy to that portion of liquid, which, by its decomposition gives rise to the compound mild sulphion, and not to the portion which operates as a solvent, when the concentrated state, will it not react with iron and zinc, without any water, when, with dilution, it reacts most powerfully with those metals?

63. Some stress has been laid upon the fact, that sourness is received, excepting with the aid of water, as if to derive force for the doctrine from that old and popular, though now abandoned test of acids; but it should be recollected that it is not the water which goes to form the compound element in the "*hydracids*," erroneously so called, which confers sourness. Will any one pretend that either sulphuric or nitric acid, when concentrated, is sour? Are they not caustic? Can any crystallized organic acids be said to have a sour taste, independently of the moisture of the tongue? The hydrated oily acids being incapable of uniting with water as a solvent, have none of these vulgar attributes of acids. The absence of these attributes in prussic acid would alone be sufficient to render it inconsistent to consider them as having any connexion with the presence of hydrogen.

64. It has been remarked, that liquid carbonic acid does not combine with oxides on contact. To this I would add, that it does not combine with water under those circumstances, but, on the contrary, separates from it like oil, after mechanical mixture: nor does it, under any circumstances, unite with an equivalent proportion of water to form a hydrate. Of course, as it is not to basic water that it is indebted for its ability to become a constituent ingredient in salts, it cannot be held that this faculty is the result of a previous conversion into an *oxycarbonide of hydrogen*.

65. Chromic acid is admitted not to require water for isolation, and is not, therefore, to be considered as oxychromionide of hydrogen. Instead of bitter almonds, which consists of a *compound radical*, bearing an atom of hydrogen, and which is therefore constituted precisely as a radical doctrine requires for endowment with the attributes of an acid, it is utterly destitute of that acid reaction which hydrogen is peculiarly competent to impart. It follows that we have, on the one hand, in chromic acid, a compound endowed with the attributes of acidity, without being a hydruret of any compound radical; and, on the other hand, in bitter almonds, a hydruret of a compound radical, without any of the attributes of acidity.

66. The last argument in favour of the existence of salt radicals, to which I have to answer, is that founded on certain results of the electrolysis of saline solutions.\*

\* It is well known that Faraday employed a very simple instrument to measure the quantity of the gaseous elements of water yielded in a given time, by water subjected to the voltaic current. It consisted of a graduated tube, through the middle of which the current was conveyed by wires, so terminating within it, as to leave an interval between them through which the current, being conveyed by the electrolytic process, effected the decomposition of the intervening liquid, the resulting gases being caught and measured by the tube. This instrument has been called a *gasometer*, or *voltameter*.

Faraday found that when various substances were electrolysed, a voltmeter placed at the same time in the circuit, that for every equivalent of water decomposed in the tube, neither more nor less than an equivalent of the other body could be decomposed.

67. On subjecting a solution of sulphate of soda to electrolysis, so as to be exposed to the current employed, simultaneously with some water in a voltmeter, Daniell alleges that, for each equivalent of the gaseous elements of water evolved in the voltmeter, there was evolved at the cathode and anode, not only a like quantity of those elements, but likewise an equal number of equivalents of soda and sulphuric acid. This he considers as involving the necessity, agreeably to the old doctrine, of the simultaneous decomposition of two electrolytic atoms in the solution, for one in the voltmeter; while, if the solution be considered as holding oxysulphionide of sodium, instead of sulphate of soda, the result may be explained consistently with the law ascertained by Faraday. In that case, oxysulphion would be carried to the anode, where, combining with hydrogen, it would cause oxygen to be extricated, while sodium, carried to the cathode, and deoxidizing water, would cause the extrication of hydrogen.

68. Dr. Kane, alluding to the experiments above mentioned, and some others which I shall mention, alleges that "*Professor Daniell considers the binary theory of salts to be fully established by them.*"

69. Notwithstanding the deference which I have for the distinguished inventor of the constant battery, and disinclination for the unpleasant task of striving to prove a friend to be in the wrong, being of opinion that these inferences are erroneous, I feel it to be my duty, as a teacher of the science, to show that they are founded upon a misinterpretation of the facts appealed to for their justification.

70. It appears to me, that the simultaneous appearance of the elements of water, and of acid and alkali, at the electrodes, as above stated, may be accounted for, simply by that electrolyzation of the soda, which must be the natural consequence of the exposure of the sulphate of that base in the circuit. I will, in support of the exposition which I am about to make, quote the language of Professor Daniell, in his late work, entitled, "Introduction to Chemical Philosophy," page 413:—

"Thus we may conceive that the force of affinity receives an impulse which enables the hydrogen of the first particle of water, which undergoes decomposition, to combine momentarily with the oxygen of the next particle in succession; the hydrogen of this again, with the oxygen of the next; and so on till the last particle of hydrogen communicates its impulse to the platinum, and escapes in its own elastic form."

71. The process here represented as taking place in the instance of the oxide of hydrogen, takes place, of course, in that of any other electrolyte.

72. It is well known, that when a fixed alkaline solution is subjected to the voltaic current, that the alkali, whether soda or potassa, is decomposed; so that if mercury be used for the cathode, the nascent metal, being protected by uniting therewith, an amalgam is formed. If the cathode be of platinum, the metal, being unprotected, is, by decomposing water, reconverted into an oxide as soon as evolved. This shows, that when a salt of potassa or soda is subjected to the voltaic current, it is the alkali which is the primary object of attack, the decomposition of the water being a secondary result.

73. If in a row of the atoms of soda, extending from one electrode to the other, while forming the base of a sulphate, a series of electrolytic decompositions be induced from the cathode on the right, to the anode on the left, by which each atom of sodium in the row will be transferred from the atom of acid with which it was previously combined, to that next upon the right,

causing an atom of the metal to be liberated at the cathode; this oxidizing water, will account for the soda and hydrogen at the cathode. Meanwhile the atom of sulphate on the left, which has been deprived of sodium, must simultaneously have yielded to the anode the oxygen by which this metal was oxidized. Of course the acid is left in the hydrogen usually called free, though more correctly esteemed to be that of a soda of water.

74. I cannot conceive how any other result could be expected in the electrolysis of the base of sulphate of soda, than that which is here described. Should any additional illustration be requisite, it will be in a note subjoined.\*

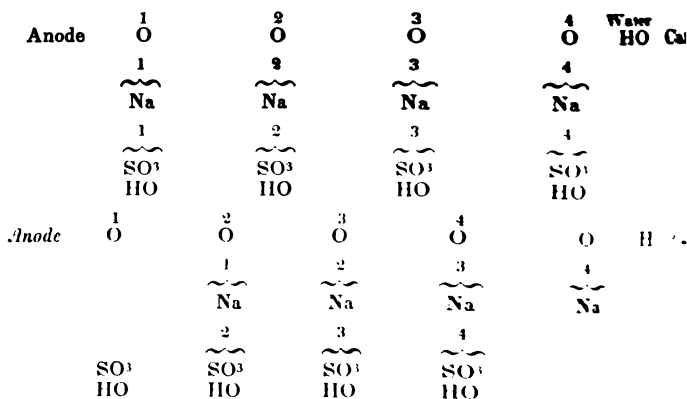
75. I will, in the next place, consider the phenomena observed by Professor Daniell, when solutions of potassa and sulphate of copper, separated by a membrane, were made the medium of a voltaic current.

76. Of these I here quote his own account. *Philosophical Magazine*, Vol. 17, p. 172:—

"A small glass bell, with an aperture at top, had its mouth closed by a piece of thin membrane over it. It was half filled with a dilution of caustic potassa, and suspended in a glass vessel containing :

\* It is easy to understand how a simultaneous appearance of oxygen at the anode, and soda and hydrogen at the cathode, may ensue, simply by the liberation of the alkaline base from the following association of formulae.

Anhydrous sulphuric acid is represented by the usual formula,  $\text{SO}^3$ ; as the usual symbol, O; sodium by Na; water, acting as a solvent, by HO. Each of oxygen, sodium, or acid, is numbered from right to left, 1, 2, 3, 4, so change of position consequent to electrolysis may be seen.



As the atoms are situated in the second arrangement, the atom of oxygen, <sup>1</sup>O, at the anode, the atom of sodium, Na, with which it had been united, has been transferred to the second atom of sulphuric acid, which had yielded its sodium to the third atom of acid, <sup>3</sup>SO<sup>3</sup>, this having, in like manner, yielded its sodium to the fourth atom of acid, <sup>4</sup>SO<sup>3</sup>, from which the fourth atom of sodium, Na, had been removed by the electrolytic power. The atom of sodium thus removed from the fourth atom of acid, is represented in union with the oxygen of an atom of water, <sup>4</sup>HO, at the cathode.



neutral solution of sulphate of copper, below the surface of which it just dipped. A platinum electrode, connected with the last zinc rod of a large constant battery of twenty cells, was placed in the solution of potassa; and another, connected with the copper of the first cell, was placed in the sulphate of copper immediately under the diaphragm which separated the two solutions. The circuit conducted very readily, and the action was very energetic. Hydrogen was given off at the platinum in a solution of potassa, and oxygen at the zinc in the sulphate of copper. A small quantity of gas was also seen to rise from the surface of the diaphragm. In about ten minutes the lower surface of the membrane was found beautifully coated with metallic copper, interspersed with oxide of copper of a black colour, and hydrated oxide of copper of a light blue.

"The explanation of these phenomena is obvious. In the experimental cell we have two electrolytes separated by a membrane, through both of which the current must pass to complete its circuit. The sulphate of copper is resolved into its compound anion, sulphuric acid + oxygen (oxysulphion), and its simple cathion, copper: the oxygen of the former escapes at the zinc, but the copper on its passage to the platinum is stopped at the surface of the second electrolyte, which for the present we may regard as water improved in its conducting power by potassa. The metal here finds nothing by combining with which it can complete its course, but being forced to stop, yields up its charge to the hydrogen of the second electrolyte, which passes on to the platinum, and is evolved.

"The corresponding oxygen stops also at the diaphragm, giving up its charge to the anion of the sulphate of copper. The copper and oxygen thus meeting at the intermediate point, partly enter into combination, and form the black oxide; but from the rapidity of the action, there is not time for the whole to combine, and a portion of the copper remains in the metallic state, and a portion of the gaseous oxygen escapes. The precipitation of blue hydrated oxide doubtless arose from the mixing of a small portion of the two solutions."

77. It will be admitted, that agreeably to the admirable researches of Faraday, there are two modes in which a voltaic current may be transmitted, *conduction* and *electrolyzation*. In order that it may pass by the last mentioned process, there must be a row of anions and cathions forming a series of electrolytic atoms extending from the cathode to the anode. It is not necessary that these atoms should belong to the same fluid. A succession of atoms, whether homogeneous, or of two kinds, will answer, provided either be susceptible of electrolyzation. Both of the liquids resorted to by Daniell, contained atoms susceptible of being electrolyzed. If his idea of the composition of sulphate of copper, and the part performed by the potassa, were admitted for the purpose of illustration, we should, on one side of the membrane, have a row of atoms consisting of oxysulphion and copper; on the other, of oxygen and hydrogen.

78. Recurring to Daniell's own description of the electrolyzing process, above quoted, an atom of copper near the anode being liberated from its anion, oxysulphion, and charged with electricity, seizes the next atom of oxysulphion, displacing and charging an atom of copper therewith united. The cupreous atom thus charged and displaced, seizes a third atom of oxysulphion, subjecting the copper, united with it, to the same treatment as it had itself previously met with. This process being repeated by a succession of similar decompositions and recompositions, an electrified atom of copper is evolved at the membrane, where there is no atom of oxysulphion. Were there *no other anion* to receive the copper, evidently the electrolyzation would not have taken place; but oxygen, on the one side of the membrane, must succeed to the office performed by oxysulphion on the other

pagation of that electrolytic process, by which as alleged, "*pass to the platinode*," i. e. catho

80. In these strictures I am fully justified by Faraday, which I quote from his Researches, §

"A single ion, i. e. one not in combination with a tendency to pass to either of the electrodes, and without the passing current, unless it be itself a compound and so subject to actual decomposition."

"If, therefore, an ion pass towards one of the electrodes, it must also be passing simultaneously to the other. If, therefore, a secondary action, it may not make its appearance."

81. In explanation of the mixed precipitate formed between the alkali and acid, the oxide from the alkali acting as a cathion in place of that of the metallic copper is to be attributed to the solution of the copper and as electrolytes; so that, at the membrane formed, which enabled a portion of the copper to combine with an anion, and a portion of oxygen to unite with a cathion. In this explanation I allude to an account of a well known experiment by Faraday, in which magnesia and water was made to act as electrolytes respectively.

82. There can, I think, be no better proof than is afforded by the experiments with membranes, in which the existence of compound radicals in acids is proved, into which an investigator, so sagacious as myself, has been led, in explaining the complicated results.

83. The association of two electrolytes, and the results between the potassa and acid, which is admitted to be an oxide, seem rather to have created difficulties than to have cleared them up.

84. In this view of the subject, I am supported by the experiments of Faraday, as expressed in the following language:—

"When other metallic solutions are used, such as those of oxides, as that of copper combined with this or

85. I cannot conceive, that in any point of view the complicated and "confused" results of the experiment of Daniell with electrolytes separated by membranes, are rendered more intelligible by supposing the existence of salt radicals. I cannot perceive that the idea that the anion in the sulphate is oxysulphion, makes the explanation more satisfactory than if we suppose it to be oxygen. Were a solution of copper subjected to electrolysis alone, if the oxide of copper were the primary object of the current, the result would be analogous to the case of sodium, excepting that the metal evolved at the cathode, not decomposing water, would appear in the metallic form. If water be the primary object of attack, the evolution of copper would be a secondary effect.

86. It is remarkable, that after I had written the preceding interpretation of Daniell's experiments, I met with the following deductions stated by Matteuchi, as the result of an arduous series of experiments, without any reference to those of Daniell above mentioned. It will be perceived that these deductions coincide perfectly with mine.

87. I subjoin a literal translation of the language of Matteuchi from the *Annales de Chimie et de Physique*, tome 74, 1840, page 110:—

"When salt, dissolved in water, is decomposed by the voltaic current, if the action of the current be confined to the salt, for each equivalent of water decomposed in the voltameter, there will be an equivalent of metal at the negative pole, and an equivalent of acid, plus an equivalent of oxygen, at the positive pole. The metal separated at the negative pole will be in the metallic state, or oxidized according to its nature. If oxidized, an equivalent of hydrogen will be simultaneously disengaged by the chemical decomposition of water."

88. Thus it seems, that the appearance of acid and oxygen at the anode, and of alkali and hydrogen at the cathode, which has been considered as requiring the simultaneous decomposition of two electrolytes upon the heretofore received theory of salts, has, by Matteuchi, been found to be a result requiring the electrolysis of the metallic base only, and, consequently, to be perfectly reconcilable with that theory.

89. In fact I had, from the study of Faraday's Researches, taken up the impression, that the separate appearance of an acid and base, previously forming a salt, at the voltaic electrodes, was to be viewed as a secondary effect of the decomposition of the water or the base; so that acids and bases were never the direct objects of electrolytic transfer.

#### *Of Liebig's "Principles," so called.*

90. Under the head of the "theory of organic acids," in Liebig's *Treatise on Organic Chemistry*, we find the following allegations dignified by the name of principles. Manifestly they must tend to convey a false impression to the student, that hydrogen has a peculiar property of creating a capacity for saturation, instead of being only the measure of that capacity, as is actually true, and likewise that in this respect it differs from any other radical.

91. The allegations to which I refer are as follows, being a literal translation from the French copy of the *Traité* of Liebig, page 7:—

"The hydrated acids are combinations of one or more elements with hydrogen, in which the latter may be replaced wholly or in part by equivalents of metals."

"The capacity of saturation depends consequently on the quantity of hydrogen which can be replaced.

"The compound formed by the other elements being considered radical, it is evident that the composition of this radical can exercise influence on the capacity of saturation.

"The capacity of saturation of these acids augments or diminishes in the same ratio as the quantity of hydrogen, not entering into the salt radical, augments or diminishes.

"If into the composition of the salt radical there should be introduced an undetermined quantity of any elements, without changing the quantity of hydrogen extraneous to the radical, the atomic weight of the acid would be augmented, but the capacity of saturation would remain the same."

92. As by the advocates of the existence of "*salt radicals*," hydrogen is considered as playing the part of a metallic radical, and must, therefore, as respects any relation between it and the capacity of saturation, be in the same predicament as any other electro-positive radical, I cannot conceive wherefore laws, which affect every other body of this kind, should be stated as if particularly associated with hydrogen.\*

93. Would not a more comprehensive and correct idea be presented by the following language?—

94. From any combination of an acid with a base, either the base or its radical may be replaced by any other radical or base, between which and the other elements present, there is a higher affinity. Of course from acid called hydrated, from their holding an atom of basic water, either this base, or its radical (hydrogen), may be replaced by any other competent base or radical.

95. The premises being manifestly fallacious, still more so is the subsequent allegation, that in consequence of the hydrated acids being compounds formed with hydrogen, their capacity of saturation depends on the quantity of this element which can be replaced.

96. Is not this an inversion of the obvious truth, that the quantity of hydrogen present is as the capacity of saturation; and that, of course, the quantity of any element which can be substituted for it, must be in equivalent proportion? Would not a student, from this, take up two erroneous

\* There is, in some respects, a coincidence so remarkable as to the part taken by Dr. Kane and myself, with respect to hydrogen, that I quote here the language which has been held by us respectively on this subject.

Treating of hydrogen, Dr. Kane uses the following words:—"It was at our time supposed that it shared with oxygen the power of generating acids; and as sulphur, chlorine, iodine, cyanogen, &c., formed one class by combining with oxygen, they formed a second class, called hydracids, by entering into union with hydrogen."

\* \* \* In the year 1832 I proved this view to be incorrect, that all the properties of the compounds of hydrogen combined to show that it was an eminently electro-positive body, that it took place along with iron, manganese, and zinc.

"These views have been still farther corroborated by the researches of Graham." \* \* \* There rests now, no doubt, in the minds of philosophical chemists, the hydrogen is a metal enormously volatile.

This justifies the following language held in my letter on the Berzelianomenclature.

"I am of opinion that the employment of the word hydracid, as co-ordinate with oxacid, must tend to convey the erroneous idea, with which, in opposition to his own definition, the author seems to have been imbued, that hydrogen in the one class plays the same part as oxygen in the other. But in reality, the former is eminently a combustible, and of course the radical, by his own definition."

So entirely have I concurred in considering hydrogen as an ætiform metal, that for more than twenty years, I have, in my lectures, accounted for the amalgamation of mercury when electrolysed in contact with sal ammoniac, by inferring ammoniac to be a gaseous alloy of two metallic ingredients, hydrogen and nitrogen being both ætiform metals.

—first, that the capacity of saturation is conferred by the radical, and in the next place, that of all radicals, hydrogen alone can give such a capacity? Is it not plain, that the assertion here made by the celebrated author would be true of any radical?

. Passing over a sentence which has no bearing on the topic under discussion, in the fourth allegation we have a reiteration and expansion of error of those by which it is preceded. We are informed that the "*capacity of saturation augments and diminishes with the quantity of hydrogen which can be replaced*," which is again an inversion of the truth, the quantity of hydrogen varying with the capacity, the quantity of other radical, competent to replace it, must be in equivalent proportion.

. Is not the concluding allegation a mere truism, by which we are misled, "that if any undetermined quantity of any element should be introduced into the composition of the radical, without changing the capacity measured by hydrogen), the capacity would be found the same when measured by any other radical?"

. As all that is thus ascribed to hydrogen must be equally true of other radical, there would have been less liability to misapprehension, had the generic term radical been employed wherever hydrogen is mentioned. But by employing the word radical to designate halogen elements, advocates of the existence of compound radicals in amphide salts have perverted the word in question of much of its discriminating efficacy. In their nomenclature would confound all ultimate elements under one generic appellation, and all their binary combinations under another, so that not every chemical reagent, whether simple or compound, would be called a radical.

10. Before concluding, I feel it to be due to the celebrated German chemist above mentioned, to add, that however I may differ from him as to the being hydrurets of compound radicals, I am fully disposed to make acknowledgments for the light thrown by his analytical researches on organic chemistry, and the successful effect of his ingenious theoretic speculations, in rendering that science more an object of study with physicians and agriculturists.



## AN ABSTRACT

*From Kane's Elements, of the Arguments in Favour of the Existence of Compound Radicals in Amphide Salts.*

It appears proper to give the student of this text book, the option of studying the arguments which it is the object of the preceding pages to refute. Hence I subjoin the following abstract from Kane's Elements, page 681:—

"It had been long remarked as curious, that bodies so totally different in composition as the compound of chlorine with a metal on the one hand, and of an oxygen acid with the oxide of the metal on the other, should be so similar in properties, that both must be classed together as *salts*, and should give origin to series of basic and acid compounds for the most part completely parallel. This difficulty has been so much felt by the most enlightened chemists, that doubts have been raised as to whether the acid and base, which are placed in contact to form by their union an oxygen salt, really exist in it when formed; and it has been suggested, that at the moment of union a new arrangement of elements takes place, by which the structure of the resulting salt is assimilated to that of a compound of chlorine or of iodine with a metal. This view, at first sight so far-fetched, which considers that in glauber's salt there is neither sulphuric acid, nor soda, but sulphur, oxygen, and sodium, in some other and simpler mode of combination, is now very extensively received by chemists; and I shall proceed, therefore, to describe with some detail the form which it has assumed, and the evidence by which it is supported.

The greater number of those bodies which are termed oxygen acids, have not been in reality insulated, and what are popularly so called are merely supposed to contain the dry acid combined with water. Thus the nearest approach we can make to nitric acid, is the liquid  $\text{NO}^2\text{H}$ ; to acetic acid, the crystalline body  $\text{C}^4\text{H}^2\text{O}^4$ ; and to oxalic acid, the sublimed crystals  $\text{C}^2\text{O}^4\text{H}$ ; we look upon these bodies as being combinations of the *dry acid* with water, and we write their formulæ  $\text{NO}^2 + \text{HO}$ , and  $\text{C}^4\text{H}^2\text{O}^3 + \text{HO}$  and  $\text{C}^2\text{O}^3 + \text{HO}$ , but that these dry acids exist at all is a mere assumption. Hence with regard to these instances, and they embrace the majority of all known acids, the idea that the acid and base really exist in the salt formed by the action of hydrated acids on a base, is purely theoretical.

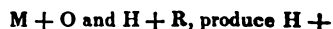
When we compare the constitution of a neutral salt with that of the hydrated acid by which it is formed, we find the positive result to be the substitution of a metal for the hydrogen of the latter, thus,  $\text{SO}^2 + \text{HO}$  gives with zinc  $\text{SO}^2 + \text{ZnO}$ ; and where a metal is acted on by an hydrated acid, the hydrogen is thus evolved either directly as gas, or it reacts on the elements of the acid and gives rise to secondary products which are evolved, such as sulphurous acid, nitric oxide, &c. In all cases we may consider the action of a metal on a hydrated acid, to be primarily the elimination of hydrogen and the formation of a neutral salt. But in this respect the action becomes completely analogous to that of the metal on a hydracid, except that in the latter case a haloid salt is formed, and hence we assimilate the two classes in constitution by a very simple arrangement of their formulæ.

There are, however, a number of acids which may be obtained in a dry and isolated form, as the sulphuric, the silicic, the telluric, the stannic, the arsenic, the phosphoric, &c., and when they combine with bases, it is most natural to consider the union as being direct, and that the salt contains acid and base really as such. This is accordingly the strongest point of the ordinary theory. But other and important circumstances intervene. These acids, although they may be obtained free from water, yet in that state they combine with bases but very feebly, and require a high temperature in order to bring their affinities into play. On the other hand, in all cases where these bodies manifest their acid characters in the highest degree, they are combined with water, as in oil of vitriol and phosphoric acid, and when expelled from combination with a base, they immediately enter into combination with water in an equivalent proportion. Thus where phosphate of lime is decomposed by oil of vitriol, it is not phosphoric acid ( $\text{PO}^3$ ) which is found in the liquor, but its

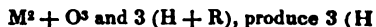
would exist to their union which should not occur very acid in vapour, and yet cold barytes and oil of vitriol as to produce ignition, whilst the barytes may combine with the dry sulphuric acid. The water, therefore, is a manifestation of strong acid properties, and it does not merely as a base. What, then, is the constitution of the acid?

When muriatic acid ( $\text{HCl}$ ) acts on zinc, the zinc and hydrogen is expelled, and if, in place of zinc, copper is the same, except that the hydrogen combining with water;  $\text{HCl}$  and  $\text{ZnO}$  giving  $\text{ZnCl}$  and  $\text{HO}$ . Now sulphuric acid  $\text{SO}^2\text{H}$  combined together; when put in contact with  $\text{ZnO}$   $\text{SO}^2\text{Zn}$  is formed, and with  $\text{ZnO}$  and  $\text{SO}^2\text{H}$ , there is no gas set free. In both cases, of which the former may be considered a haloid salt and the latter of all salts formed by oxygen and hydrogen which is removable by a metal, precisely as in the case of the other, as indeed from the real metallic character of the acid may occur in this case. Every acid may, therefore, be considered as combined with an electro-negative element, which may be fluorine; or may be compound, as cyanogen,  $\text{NC}^2$ , or as occurs in the great majority of cases, its elements remain together when in combination. Thus oil of vitriol is  $\text{HO}$ , but consists of hydrogen united to a compound which does not contain  $\text{NO}^2$  and  $\text{HO}$ , but consists of hydrochloric  $\text{NO}^2$ , and the acetic acid is written  $\text{C}^2\text{H}^2\text{O}^4 + \text{HO}$  so on.

The elegance and simplicity with which the laws are deduced from these principles is really remarkable. A fact substantiated by experiment, that in neutral salts the number of atoms of acid were proportional to the number of equivalents of the base, the ordinary theory gave no indication of why this was the case, but is easily deduced from the principles of the newer theory. Thus if  $\text{M}$  denote the metal of the oxide, and  $\text{R}$  the acid, the action is



and in the neutral salt there is an equivalent of each of the oxide, in order that water shall be formed, and so the reaction is that



a sesqui-compound being formed perfectly analogous to the neutral salt, the number of atoms of acid,  $3 (\text{H} + \text{R})$ , is equal to the number of atoms of base ( $\text{M}^2\text{O}^2$ ), because that number of atoms of hydrogen is required to saturate the oxygen of the base. In like manner for a deutoxid



ence there is no other proof than their utility in supporting this view, becomes more powerful as an objection, when we proceed to apply its principles to the salts of phosphoric acid. For it has been already described, that this acid forms three distinct classes of salts, all neutral, and which have their origin in the three hydrated states of the phosphoric acid. These states are written on the two views as follows:—

	Old Theory.	New Theory.
Monobasic acid,	$\text{PO}^5 + \text{HO}$	$\text{PO}^6 + \text{H}$
Bibasic acid,	$\text{PO}^5 + 2\text{HO}$	$\text{PO}^7 + \text{H}^2$
Tribasic acid,	$\text{PO}^5 + 3\text{HO}$	$\text{PO}^8 + \text{H}^3$

Now it appears very useless, where the older view accounts so simply for the properties and constitution of these salts, to adopt so violent an idea, as that there are three distinct compounds of phosphorus and oxygen which no chemist has ever been able to detect. But here again other circumstances must be studied; first, the difference of properties of phosphoric acid, in its three states, is totally inexplicable, on the idea of their being merely three degrees of hydration. Nitric acid forms three hydrates, but when neutralized by potash, it always gives the same saltpetre; sulphuric acid forms two perfectly definite hydrates, but with soda forms always the same glauber's salt; whilst phosphoric acid, when neutralized by soda, gives a different kind of salt according to the state it may be in. Also, the permanence of these conditions of phosphoric acid is a powerful proof that they do not consist in the adhesion of mere water. The idea that the phosphoric acid is a different hydracid in each of its three conditions, on the other hand, not merely explains the fact of these differences of properties, but it renders the formation of bibasic and tribasic salts, which is such an anomaly on the old theory, a necessary consequence of the new, for the phosphoric salt radicals,  $\text{PO}^6$ ,  $\text{PO}^7$ , and  $\text{PO}^8$ , differ not merely in the quantity of oxygen they contain, but are combined with different quantities of hydrogen, and hence in acting on metallic oxides (bases), there is a different number of atoms required for each to replace the hydrogen and form water. Thus—

$\text{PO}^6.\text{H}$  and  $\text{NaO}$  give  $\text{HO}$  and  $\text{PO}^6.\text{Na}$ . monobasic phosphate of soda,  
 $\text{PO}^7.\text{H}^2$  and  $2\text{NaO}$  give  $2\text{HO}$  and  $\text{PO}^7.\text{Na}^2$ . bibasic phosphate,  
 $\text{PO}^8.\text{H}^3$  and  $3\text{NaO}$  give  $3\text{HO}$  and  $\text{PO}^8.\text{Na}^3$ . tribasic phosphate.

A circumstance which gives additional reason to infer that the water is not merely as base in the phosphoric acid, is the following: if it were so, then it should be most completely expelled by the strongest bases, and the bibasic and tribasic phosphates of the alkalis should be those least likely to retain any portion of the basic water; but the reverse is the fact; whilst oxide of silver, a very weak base, is that which most easily and totally replaces the water. On the idea, however, of hydracids, this is easily understood, for the oxide of silver is one most easily reduced by hydrogen, and consequently one on which the action of a hydrogen acid, as  $\text{PO}^6 + \text{H}^3$ , or  $\text{PO}^7 + \text{H}^2$ , would be most completely exercised.

A remarkable verification of this theory has been recently found in the decomposition of solutions of the oxy-salts in water, by voltaic electricity. It has been already explained (pp. 314 *et seq.*), that it requires the same quantity of electricity to decompose an equivalent of any binary compound, such as iodide of lead, chloride of silver, muriatic acid, or water. Now, if we dissolve sulphate of soda in water, and pass a current of voltaic electricity through that solution, we have water decomposed, and also the glauber's salt; oxygen and sulphuric acid being evolved at one pole, and soda and hydrogen at the other. Here, on the old view, the electricity performs two decomposing actions at the same time, and, as it thus divides itself, its action on each must be lessened, and the quantity of each decomposed be diminished, so that the sum should represent the proper energy of the current. On measuring these quantities, however, the result is totally different, the quantity of sulphate of soda decomposed is found to be equal to the full duty of the current, and an equivalent of water appears to be decomposed in addition. It is quite unphilosophic to imagine, that the strength of a current should be thus suddenly doubled, and a simple and sufficient explanation of it is found in the new theory of salts. The sulphate of soda in solution having the formula  $\text{Na}.\text{SO}^4$  is resolved by the current into its elements,  $\text{Na}$  and  $\text{SO}^4$ , as chloride of sodium would also be; the sodium, on emerging at the negative electrode, from the influence of the current, instantly decomposes water, and soda and hydrogen, of each an equivalent, are evolved; at the positive electrode the compound radical  $\text{SO}^4$  also decomposes water, and produces  $\text{H}.\text{SO}^4$  and  $\text{O}$ . The appearance of the oxygen and hydrogen is thus but secondary, and the body really decomposed by the current is only  $\text{Na}.\text{SO}^4$ .

In the case of the salts of such metals as do not decompose water, the phenomena

are much more simple. Thus a solution of sulphate of copper, when decomposed by the battery, yields metallic copper at the negative, and sulphuric acid and oxygen at the positive electrode, and the quantity of copper separated represents exactly the energy of the current which has passed, for the salt being  $\text{Cu.SO}_4$ , is simply resolved into its elements, but  $\text{SO}_4$  reacting on the water, produces  $\text{H}_2\text{SO}_4$  and  $\text{O}$  at the positive electrode. On the old view, it was supposed that water and sulphate of copper were both decomposed, oxygen and acid being evolved at one side, and oxide of copper and hydrogen being separated at the other; which reacting produced water at the metal. Such an explanation, however, is directly opposed to the law of the definite action of electricity, and cannot be received.

In the case of solutions of chlorides or iodides, where there can be no doubt of the relations of the elements, the results of voltaic decomposition are precisely similar. Chloride of copper gives simply chlorine and copper, no water being decomposed. Chloride of sodium or iodide of potassium give chlorine or iodine at the one electrode, and alkali and hydrogen at the other; the evolution of these last being caused by the action of the metallic basis on the water of the solution.

Professor Daniell, to whom these important electro-chemical researches are due, considers the truth of the binary theory of salts to be fully established by them.

If this theory be adopted, a profound change in our nomenclature of salts will become necessary. Graham has proposed that the name of the salt radical should be formed by prefixing to the word *oxygen* the first word of the ordinary name of the class of salts, and that the salts be termed by changing *oxygen* into *oxide*. Thus  $\text{SO}_4$ , *sulphatoxygen*, gives sulphatoxides, the sulphates.  $\text{NO}_3$ , *nitratooxygen*, gives nitratooxides, the nitrates, and so on; but I consider that the form of nomenclature proposed by Daniell deserves the preference. It has been described (p. 314), that Faraday proposed to term the elements which pass to the electrodes of the battery, *ions*; acting on this, Daniell proposes to term the electro-negative element of the sulphates *oxysulphion*, that of the nitrates *oxynitron*, and so on, and the salts may be termed *oxysulphion* of copper, *oxynitron* of sodium, &c. It would be desirable, however, for a long time, to introduce these names only where theoretical considerations rendered their employment decidedly useful, and hence, in all future description of the salts, I shall make use of the language of our ordinary views, and trust that their preparation and composition without any reference to the discussion in which we have been engaged.

The general adoption of the binary theory of salts has deprived of much of its interest and importance a question, which some years since was very ingeniously discussed, viz.—whether, in the formation of double salts, the salts which unite had the same relation to each other that acid and base were then thought to have. Then it was supposed that the electro-negative qualities of sulphuric acid being less controlled by oxide of copper than by potash, the alkaline sulphate acted as a base to the sulphate of copper, when these two salts combined to form the double sulphate of potash and copper, and so on in other instances; but in addition to the circumstance that all we have said as to the constitution of the salts militates against this view, we have the positive evidence that, first, these double salts are formed not by combination merely, but by replacement of the constitutional water of the sulphate of the copper or magnesian class, which water nobody would contend to act as a base; and second, that when a solution of such a double salt is decomposed in the battery, the two salts are not separated as if they were acid and base, but are decomposed independently in the proportions of an equivalent of each, making together the sum of the chemical energy of the current.

A similar idea was advocated by Bonsdorff regarding the double chlorides, iodides &c. He proposed to consider the chlorides of gold, platina, mercury, &c. as chlorine acids, and those of potassium, &c., as chlorine bases, and so with the iodides. This view, however, although at first very extensively adopted, has given way to the gradual growth of knowledge. There is no analogy between a dry argentic chloride and a chloride; but the chlorides are in perfect analogy with the neutral salts. Thus  $\text{CuCl}$  does not resemble  $\text{SO}_3$ , but  $\text{Cu.SO}_4$  and  $\text{CuCl} + \text{KCl}$  is analogous to  $\text{SO}_3.\text{K}_2\text{O}$ , but to the double salt  $\text{Cu.SO}_4 + \text{K.SO}_4$ . Bonsdorff's idea was not only counter to the direction of truth; he sought to bring all salts under the one head, extending to all the constitution of oxygen acids and oxygen bases, whilst the progress of science has led us to the opposite generalization of reducing all salts to the simple haloid type."

J. G. AUNER'S CATALOGUE.

---

# NEW BOOKS

RECENTLY PUBLISHED

BY

**JOSEPH G. AUNER,**

No. 333 MARKET STREET,

PHILADELPHIA.

---

## **HORNER'S PRACTICAL ANATOMY.**

Lessons in Practical Anatomy, for the Use of Dissectors.  
By W. E. Horner, M. D., Professor of Anatomy in the University of Pennsylvania, Surgeon at the Philadelphia Hospital, *Blockley*, &c. 1 vol. 8vo., 3d edition, enlarged and improved.

---

## **HARE'S CHEMISTRY.**

A Compendium of the Course of Chemical Instruction in the Medical Department of the University of Pennsylvania. By Robert Hare, M. D., Professor of Chemistry in the University of Pennsylvania. 1 vol. 8vo., 4th edition, with amendments and additions.

**GODDARD ON THE NERVES.**

Plates of the Cerebro-Spinal Nerves, with references, for the use of Medical Students. By Paul B. Goddard, M.D., Demonstrator of Anatomy in the University of Pennsylvania, Member of the Academy of Natural Sciences, of the Philadelphia Medical Society, &c. &c. 1 vol. quarto. Twelve plates.

"We recommend this volume to form a part of the library both of the student and practitioner."—*American Medical Library and Intelligence*.

**GODDARD ON THE ARTERIES.**

Plates of the Arteries of the Human Body, with copious references. By Paul B. Goddard, M.D., Demonstrator of Anatomy in the University of Pennsylvania, Member of the Academy of Natural Sciences, of the Philadelphia Medical Society, &c. &c. 1 vol. 4to. 12 coloured plates.

**WARRINGTON'S OBSTETRIC CATECHISM.**

The Obstetric Catechism. By Joseph Warrington, M.D. 1 vol. 12mo.

**CHASE ON HERNIA.**

A Treatise on the *Retention and Radical Cure of Hernia*, with advice to patients on the precautionary measures required to insure their safety; and an analysis of the instruments employed in the treatment of this disease; with a detailed account of numerous improvements, addressed to the profession and the public; with plates. By Heber Chase, M.D., Honorary Member of the Philadelphia Medical Society, &c. 1 vol. 8vo.

**HAINES' CATECHISM ON CHEMISTRY.**

Catechism on Chemistry, adapted to the Course of Lectures delivered in the University of Pennsylvania. By Isaac S. Haines, M.D. 1 vol. 18mo. 3d edition.

---

**LOBSTEIN ON THE SYMPATHETIC NERVE.**

A Treatise on the Structure, Functions and Diseases of the Human Sympathetic Nerve, illustrated with plates. By John Frederick Lobstein, Professor of Clinical Medicine and Pathological Anatomy in the Medical Faculty of Strasburg, First Obstetric Physician to the City Hospital, and Member of many Learned Societies. Translated from the Latin, with notes, by Joseph Pancoast, M.D. 1 vol. 8vo.

---

**BARTON'S MATERIA MEDICA & BOTANY.**

Outlines of Lectures on Materia Medica and Botany, delivered in Jefferson Medical College, Philadelphia. By William P. C. Barton, M.D. 2 vols. 12mo.

---

**CHASE'S MEDICAL STUDENT'S GUIDE.**

The Medical Student's Guide; being a compendious view of the Collegiate and Clinical Medical Schools; the Courses of Private Lectures; the Hospitals and Almshouses, and other Institutions, which contribute directly or indirectly to the Great Medical School of Philadelphia; with the Regulations of Hours, Fees, &c., and other information of importance to Students. By Heber Chase, M.D. 1 vol. 18mo.

### **DYER'S SACRED MUSIC.**

Dyer's Selection of Sacred Music, consisting of about three hundred approved Psalm and Hymn Tunes; from the works of the most esteemed authors, ancient and modern, arranged for four voices, and adapted to all the metres in general use amongst the various religious denominations; and a concise Introduction to the Art of Singing, with Lessons and Examples, according to the English and Italian methods. By Samuel Dyer. 1 vol. 8vo.

---

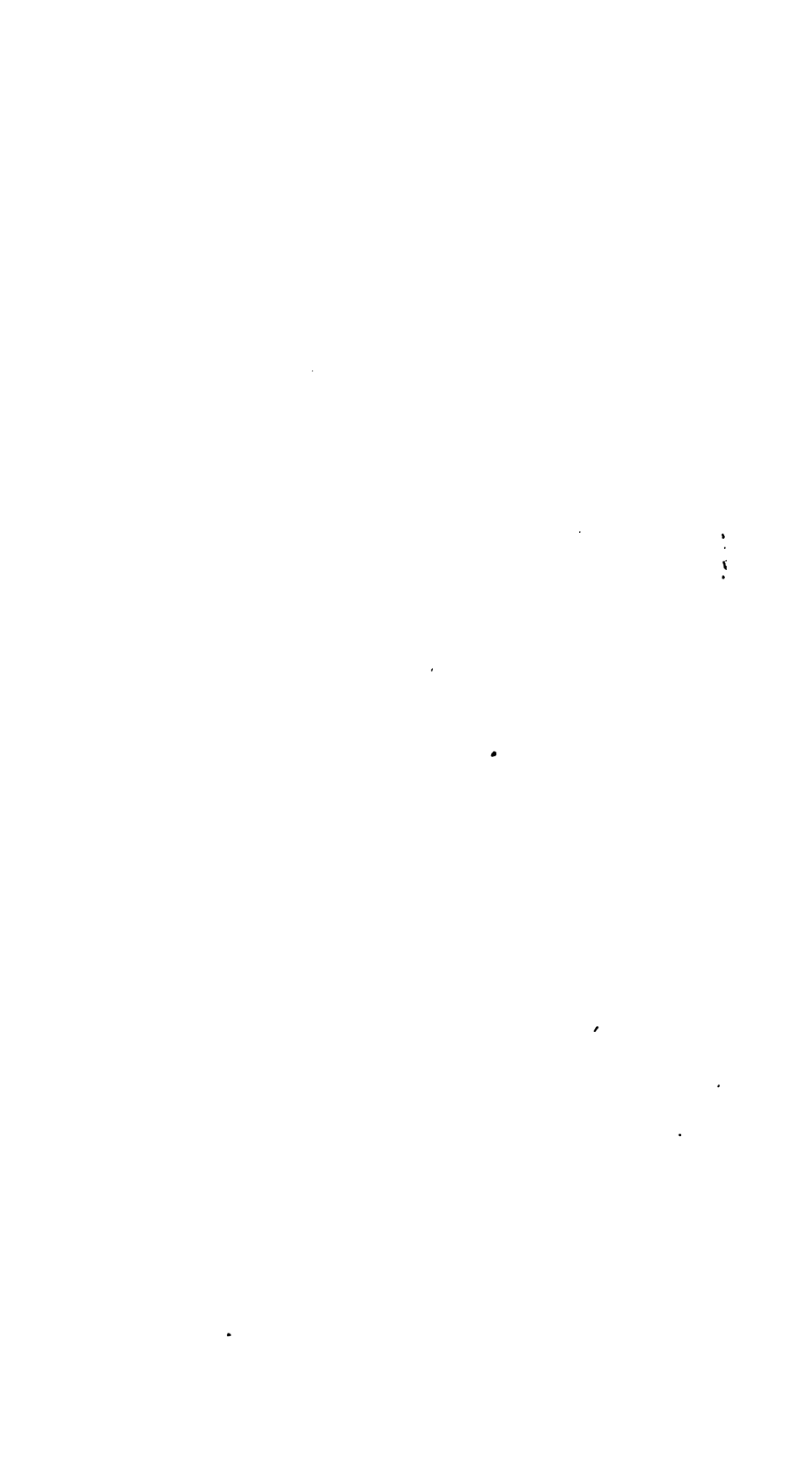
### **DYER'S ANTHEMS.**

A Selection of upwards of Eighty favourite and approved Anthems, Set Pieces, Odes and Choruses, from the works of the most approved authors; many of which have never before been published in this country, and several of them are original, and composed expressly for this work; with Biographical Sketches of the Several Composers. By Samuel Dyer. 1 vol. super-royal 8vo.

---

### **DYER'S CHORUSES.**

Choruses, Solos, Duets and Recitatives, from the works of Handel, Haydn, Mozart, Beethoven, and other composers of the first eminence, arranged in full vocal score, and interspersed with Notes and Explanatory Remarks. By Samuel Dyer. 1 vol. 4to.







# MEDICAL BOOKS

FOR SALE BY

JOSEPH G. AUNER,

BOOKSELLER AND STATIONER,

No. 333 MARKET STREET, BELOW NINTH STREET,

PHILADELPHIA:

---

## TEXT BOOKS.

COMPLETE SETS OF THE MEDICAL TEXT BOOKS

---

In addition to the following Catalogue, all the new publications will  
received as soon as published.

---

### MEDICAL, CHEMICAL, BOTANICAL, &c.

Andral on the Blood.  
Aran on the Heart.  
Alimentary Canal.  
Abercrombie on the Stomach, &c.  
Abercrombie on the Brain.  
Abernethy on Tumour.  
Accum on Culinary Poisons.  
Accum's Chemistry, 3 vols.  
Ackerlay on Children.  
Acupuncture, by Morand.  
Aiken on the Cow-Pox.  
Allison's Pathology.  
Amussat on Urine.  
Andral's Medical Clinic, 3 vols.  
Armstrong on Typhus Fever.  
Armstrong on Puerperal Fevers.  
Armstrong's Practice, 2 vols.  
Arnott's Elements of Physics.  
Ashwell on Females.  
Assalina on the Plague.  
Averill's Surgery.  
Ayre on the Liver.

Bell's Institutes of Surgery.  
Bell & Stokes's Practice, 3 vols.  
Bampfild on the Spine, by Mitchell.  
Bartlett's Philosophy of Medicine.  
Brigham on the Brain.  
Brigham on Mental Culture.  
Blundell on Females.  
Budd on the Liver.

Barton's Lectures on Materia Medica  
and Botany, 2 vols.  
Bartlett on Typhoid and Typhus.  
Billing's Principles of Medicine.  
Baudelocque's Puerperal Peritonitis.  
Broussais' Pathology.  
Boisseau on Fever.  
Broussais on Insanity.  
Bichat on Pathology.  
Bichat on Life and Death.  
Barton's Elements of Botany.  
Bayle's Anatomy.  
Beck's Chemistry.  
Beck's Murray's Materia Medica.  
Bichat's Anatomy and Physiology.  
Billard on Infants.  
Burne on Constipation.  
Burns on Head and Neck.  
Burns on Abortion.  
Burns on Inflammation.  
Bushe on the Rectum.  
Bell on Baths and Mineral Waters.  
Bell's Materia Medica.  
Boyer on the Bones.  
Broussais on Inflammation, 2 vols.  
Bell's Operative Surgery.  
Bell on the Urethra.  
Bell on Ulcers.  
Bell on Wounds.  
Bell's Dissections, 2 vols.  
Bell's Anatomy, 2 vols.

# J. G. AUNER'S CATALOGUE.

Bell's Engravings of the Bones.  
 Bell's Engravings of the Nerves.  
 Bell on the Teeth.  
 Bree on Asthma.  
 Bateman on Cutaneous Diseases.  
 Brande's Chemistry, by Webster.  
 Baillie's Morbid Anatomy.  
 Blain's Medical Logic.  
 Bayle & Holland's General Anatomy.  
 Beck's Medical Jurisprudence, 2 vols.  
 Bigelow's Materia Medica.  
 Bancroft on Fever.  
 Buchan's Domestic Medicine.  
 Boyer's Surgery, 2 vols.  
 Bertin on the Heart.  
 Brera on Verminous Diseases.  
 Beddingfield's Practice.  
 Beclard's Anatomy.  
 Blake's Botany.  
 Beaumont on Gastric Juice.  
 Bellozay on the Stone.  
 Brodie on Urinary Organs.  
 Brodie on Joints.  
 Berzelius on Kidney.  
 Bouillaud on Rheumatism.  
 Blundell's Midwifery.

Chapman on Fevers, Dropsies, Gout, &c.

Cooper (Sir Astley) on the Testis and Thymus Gland.

Cooper (Sir Astley) on the Breast.

Colles' Surgical Lectures.

Cyclopedia of Practical Medicine, by Forbes, &c., edited by Dunglison, 4 vols.

Cooper's (Samuel) First Lines of Surgery, by Parker, 2 vols.

Colombat on Females, by Meigs.

Cruveilhier's Anatomy.

Chailly's Midwifery.

Carpenter's Vegetable Physiology.

Chelius & South's Surgery, 2 vols.

Coxe on Bronchitis.

Coates's Physiology.

Clarke on Climatea.

Churchill on Pregnancy.

Carpenter's Materia Medica.

Calhoun on Suspended Animation.

Carlisle on Old Age.

Cazenave on Diseases of the Skin.

Castle's Manual of Surgery.

Chapman on the Viscera.

Cholera, Bell and Condie on.

Cholera, Scoutetten on.

Ohisholm on Malignant Fever.

Cheyne on Dropsy.

Corvisart on the Heart.

Coates's Popular Medicine.

Collins's Midwifery.

Condie on Children.

Coxe's Medical Dictionary.

Cook on Nervous Diseases.

Calhoun's Prout on the Urinary Organs.

Comstock's Botany.

Combe on Infancy.

Combe on Insanity.

Comstock's Mineralogy.

Cooper (Sir A.) on Hernia.

Cooper's Lectures on Surgery, by Tyrrell.

Carmichael on Venereal.

Curling on Tetanus.

Curry on Cold Water.

Cooper & Travers's Surgical Essays.

Copeland on the Rectum.

Clutterbuck on Blood-letting.

Cooper on Dislocations.

Conversations on Chemistry.

Colles's Surgical Anatomy.

Curling on the Testis, by Goddard.

Curry on Yellow Fever.

Cutler on Bandages.

Cheyne on Croup.

Coxe on Insanity.

Cook on White Mustard Seed.

Cooper's Surgical Dictionary.

Coster's Physiological Practice.

Coxe's Refutation of Hervey's Claim.

Clark on Consumption.

Christison on Poisons.

Christison on the Kidney.

Chase on Hernia.

Chitty's Medical Jurisprudence.

Churchill's Midwifery.

Churchill on Females.

Carpenter's Human Physiology.

Civil on Stone.

Chase's Medical Student's Guide.

Dublin Practice of Midwifery.

Dunglison's Prac. of Medicine, 2 vols.

Druitt's Modern Surgery.

Dunglison's Therapeutics and Materia Medica, 2 vols.

Dick on Digestion.

Darrach on the Groin.

Davies' Pathology.

Dupuytren's Surgery.

Duparques on the Uterus.

Dunglison's New Remedies.

Dunglison's Medical Dictionary.

Dunglison's Physiology, 2 vols.

Dunglison on Hygiene.

Dunglison's Medical Student.

## J. G. AUNER'S CATALOGUE.

Deslandes on Onanism.  
 Daniel on Fever.  
 Dewees' System of Midwifery.  
 Dewees on Treatment of Children.  
 Dewees on Diseases of Females.  
 Dewees' Essays.  
 Dewees' Practice.  
 Desault's Surgery, 2 vols.  
 Denman's Midwifery, by Francis.  
 Duncan on Consumption.  
 Ducamp on Urine.  
 Doane's Surgery, illustrated.  
 Desault on Fractures.  
 Dublin Dissector.

Esquirol on Insanity.  
 Evanson and Maunsell on Children.  
 Edward's Anatomy and Physiology.  
 Ellis's Medical Formulary.  
 Eberle's *Materia Medica* and Therapeutics.  
 Eberle's Notes.  
 Eberle's Practice, 2 vols.  
 Edinburgh Dispensatory.  
 Edwards' Manual of Surgical Anatomy.  
 Edwards' Manual of *Materia Medica*.  
 Eaton's Manual of Botany.  
 Eberle on Children.  
 Ever's Comparative Anatomy.  
 Elliotson's Practice, by Stewardson.  
 Elliotson on Mesmerism.

Ferry on Climate of U. States.  
 Fowne's Elementary Chemistry.  
 Freckleton's Outlines of Pathology.  
 Fontana on Poisons, 2 vols.  
 Fordyce on Fever.  
 Ferriar's Medical Reflections.  
 Faithorn on Liver Complaint.  
 Faraday's Chemical Manipulations.  
 Fergusson's Surgery.

Guthrie on the Bladder and Urethra.  
 Guy's Medical Jurisprudence.  
 Gregory's Chemistry.  
 Gross on the Intestines.  
 Gerhard's Clinical Guide.  
 Goddard on the Arteries, 12 plates.  
 Goddard on the Nerves, 12 plates.  
 Gray's Botanical Text Book.  
 Graves and Gerhard's Clinical Lectures.  
 Gamage on Fever.  
 Gibson's Surgery, 2 vols.  
 Gunn's Domestic Medicine.  
 Gregory's Dissertation on Climates.  
 Gregory's Practice, 2 vols.

Good's Study of Medicine, 2 vols.  
 Good's Book of Nature.  
 Green on the Skin.  
 Gardner on the Gout.  
 Gallup on Epidemics.  
 Gross on the Bones and Joints.  
 Gross's Pathological Anatomy, 2 vols.  
 Goupil on the New Medical Doctrine.  
 Graham on Indigestion.  
 Gooch's Midwifery.  
 Gooch on Females.  
 Gerhard on the Chest.  
 Goddard on the Teeth, 30 plates.  
 Gibert on the Blood.  
 Graham's Chemistry.

Harrison on the Nervous System.  
 Harris on the Maxillary Sinus.  
 Holland's Medical Notes.  
 Hare's Chemistry.  
 Horner's Special Anatomy, 2 vols.  
 Hecker's Epidemics of Middle Ages.  
 Hope on the Heart.  
 Hunter's Works, 4 vols.  
 Hunter on the Blood.  
 Hunter on the Teeth.  
 Hunter on Venereal.  
 Hunter on Animal Economy.  
 Hunter's Principles of Surgery.  
 Harris's Dental Surgery.  
 Hall's (Marshall) Practice.  
 Horner's Medical and Top. Observations on the Mediterranean.  
 Haines' Catechism on Chemistry.  
 Hall on Diagnosis.  
 Hall on the Nervous System.  
 Hall on Loss of Blood.  
 Henry's Chemistry, 2 vols.  
 Hooper's Medical Dictionary.  
 Heberden's Medical Commentaries.  
 Hamilton on Purgatives.  
 Hamilton on Mercury.  
 Hamilton's Midwifery.  
 Hall on Digestive Organs.  
 Hildenbrand on Typhus Fever.  
 Hale on Spotted Fever.  
 Hufeland on Scrofulous Diseases.  
 Hatin's Manual of Obstetrics.  
 Hutin's Manual of Physiology.  
 Hennen's Military Surgery.  
 Horner's Practical Anatomy for the use of Dissectors.  
 Hosack's Practice.  
 Hall on Circulation of the Blood.

Innes on the Muscles.  
 Jones & Todd on the Ear.

## J. G. AUNER'S CATALOGUE.

Johnson & Moffatt's Chemistry.  
James' Burns' Midwifery.  
James' Merriman.  
Johnson on Civic Life.  
Johnson on the Liver.  
Johnson on the Stomach.  
Jaudon on Syphilis.  
Johnson on Cancer.  
Johnson on Change of Air.  
Jones on Hemorrhage.

Kennedy on Obstetric Auscultation.  
Kissam's Nurse's Manual.  
Kane's Elements of Chemistry.  
Kramer on the Ear.

Lee's Midwifery.  
Lee's Manual of Geology.  
Lecroq's Manual of Examinations.  
Legal on Scrofula.  
Lieber's Agricultural Chemistry.  
Lieber's Animal Chemistry.  
Lieber's Elements of Surgery.  
Lieber's Practical Surgery.  
Longshore's Principles of Nursing.  
Lawrence on the Eye.  
London Dissector.  
Laennec on the Chest.  
Laennec on the Stethoscope.  
Larrey's Surgical Essays.  
Larrey's Military Surgery, 2 vols.  
Laycock on Hysteria.  
Littell on the Eye.  
Lobstein on Phosphorus.  
London Practice of Midwifery.  
Le Gallois on Life.  
Louis on Fever, 2 vols.  
Louis on Emphysema of the Lungs.  
Louis on Phthisis.  
Louis on Yellow Fever.  
Louis on Blood-letting.  
Lisfranc on Uterus.  
Lawrence on Ruptures.  
Lincoln's Botany.  
Lobstein on the Sympathetic Nerve.  
Larrey on Injuries of the Head.

Miller's Principles of Surgery.  
Mott's Velpeau's Operative Surgery.  
Magendie's Physiology, by Revere.  
Moreau's Midwifery, 4to., plates.  
Medical Student's Vade Mecum.  
Morton on Consumption.  
Millingen on Insanity.  
Malcomson on Liver Abscess.  
Mackintosh's Practice.  
Mayo's Pathology.  
Macartney on Inflammation.

Magendie on the Blood.  
Marshall on the Heart.  
Meckel's Anatomy, 3 vols.  
Meigs' Midwifery.  
Magendie's Medical Formulary.  
Magendie on Prussic Acid.  
Montgomery on Pregnancy.  
Miner and Tully on Fevers.  
Mutter on Loxarthrus.  
Moss on Infants.  
M'Murtrie's Vade Mecum.  
Martinet's Therapeutics.  
Milman on Scurvy.  
Murray on the Arteries.  
Macculloch on Remittent and Inter-mittents.  
Macculloch on Malaria.  
Maclean on Hydrothorax.  
Mitchell's Chemistry.  
Maygrier's Anatomy.  
Maygrier's Midwifery, 200 plates.  
Möller's Physiology.  
Maury's Dental Surgery.  
Makenzie on the Eye.

Nunnelle on Erysipelas.  
Neligan on Medicines, by Reese.  
Nuttall's Botany.

Orfila on Poisons.  
Oliver's Physiology.

Prout on the Stomach and Renal Diseases.  
Pettigrew's Surgical Superstitions.  
Paine's View of the Materia Medica.  
Pancast's Surgery, 4to., plates.  
Pancoast's Wistar's Anatomy.  
Puerperal Fever, by M. G. S. W.  
Parker on Stomach and Syphilis.  
Phrenology, Combe's.  
Phrenology, Spurzheim's.  
Phrenology, Calvert's.  
Pocket Anatomist.  
Pott's Surgery, 2 vols.  
Philip on the Venæ Cavae.  
Philip on Indigestion.  
Parr's Pharmacologia.  
Parr's Medical Dietetics, 2 vols.  
Parr's Medical Chemistry.  
Paine's Commentaries, 2 vols.  
Paris on Diet.  
Pemberton on the Viscera.  
Pott on Hydrocele.  
Physician's Vade Mecum.  
Physician's Case Book.  
Parker's Chemical Catalogue.  
Phillips' Mineralogy.

# J. G. AUNER'S CATALOGUE.

Parton's Anatomy.  
 Phillips on Diseases.  
 Parson's Anatomical Preparations.  
 Parrish's Surgical Observations.  
 Parmly on the Teeth.  
 Pritchard on Insanity.  
 Plumbe on the Skin.  
 Pereira's *Materia Medica*, 2 vols.  
 Pereira on Dietetics.  
 Pilcher on the Ear.

Quain & Wilson's Anatomical Plates,  
 by Pancoast.

Rogot's Animal and Vegetable Physiology.

Ryan's Midwifery.

Renwick's Natural Philosophy.

Renwick's Chemistry.

Reese's Lexicon of Terminology.

Royle's Manual of *Materia Medica*, &c.

Rose on Consumption.

Raciborski on Auscultation.

Rogot's Outlines of Physiology.

Ray's Medical Jurisprudence.

Ramsbotham's Midwifery.

Rush on the Mind.

Rush's Hilary.

Rush's Cleghorn.

Rush's Sydenham.

Robertson's Catalogue of Minerals.

Robertson on the Teeth.

Rigby's Obstetric Memoranda.

Rigby's Midwifery.

Ricord on Venereal.

Rush on the Voice.

Rush's Pringle.

Ryland on the Stethoscope.

Ricketson on Health.

Ratier's Formulary.

Read on Consumption.

Ryan's Lectures on Marriage.

Smiley's Physician's Pocket Dose Book.

Sweetzer's Mental Hygiene.

Smith & Horner's Anatomical Atlas.

Stanley on the Bones.

Squarey's Agricultural Chemistry.

Schill's Pathological Semeiology.

Shaw's Medical Remembrancer.

Swediaur on Syphilis.

Scudamore on Gout and Rheumatism.

Smith on Typhus Fever.

Shaw's Manual of Anatomy.

Stephenson on the Eye.

Stewart on Children.

Struve on Suspended Animation.

Senac on Fevers.

Smith's Grammar of Botany.

Scofield on Cow-Pock.

Saunders on the Liver.

Saissy on the Ear.

Surgeon's Vade Mecum.

Silliman's Chemistry, 2 vols.

Smith on Fevers.

Surgeon Dentist's Manual.

Syme's Surgery.

Snell on the Teeth.

Sarlandiere's Anatomical Plates.

Stokes on the Chest.

Spurzheim on the Brain.

Scoutetten on Club-Foot.

Smith on the Arteries.

Smith's Minor Surgery.

Stewart on Club-Foot.

Spurzheim on Insanity.

Thompson's Conspectus.

Taylor's Medical Jurisprudence, by Griffith.

Trimmer's Geology and Mineralogy.

Thomson on Liver.

Twining on Liver and Spleen.

Thacher's Practice.

Teale on Neuralgia.

Trail's Medical Jurisprudence.

Thacher's Dispensatory.

Thacher on Hydrophobia.

Trotter on Drunkenness.

Timbrel on Ruptures.

Travers on the Eye.

Thomas' Practice.

Thompson on Varioloid.

Trousseau & Belloc on the Voice.

Turner's Chemistry.

Thomas' Domestic Medicine.

Thornton's Botany.

Trotter on Nervous Temperament.

Thompson on Inflammation.

Tavernier's Operative Surgery.

Tweedie on Fever.

Todd's Index Rerum.

Tusou's Dissector's Guide.

Ure's Chemical Dictionary, 2 vols.

Underwood on Diseases of Children.

United States Pharmacopoeia.

Velpeau's Midwifery, by Harris.

Velpeau on the Breast.

Vestiges of the Creation.

Velpeau's Surgery, by Mott.

Vought on Bowel Complaints.

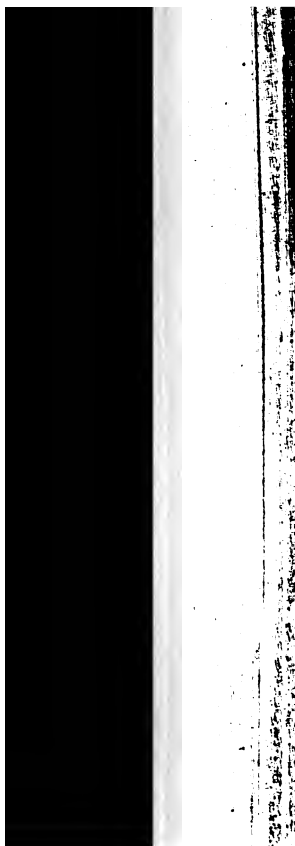
Velpeau's Anatomy, 2 vols.

J. G. AUNER'S CATALOGUE.

Williams & Clymer on Respiratory  
Organs.  
Waller on the Womb.  
Wilson's Human Anatomy, by God-  
dard.  
Williams on the Stomach.  
Williams' Am. Medical Biography.  
Wood & Bache's Dispensatory.  
Wilson's Anatomist's Vade Mecum.  
Warrington's Obstetric Catechism.  
Warrington's Nurse's Guide.  
Walker on Beauty.  
Walker on Pathology.  
Willis on Urinary Diseases.  
Williams' Principles of Medicine.  
Williams on the Chest.  
Webster's Brande's Chemistry.

Willan on the Skin.  
Winslow's Anatomy.  
Wilson on Febrile Diseases.  
Wilson on Spotted Fever.  
Williams on the Lungs.  
Williams' Catechism of Medical Je-  
risprudence.  
Walker on Woman.  
Walker on Intermarriage.  
Warren on Tumour.  
Webster on Pestilence.  
Wilson's Dissector, by Goddard.  
Watson's Practice.  
Walsh on Cancer.  
Wilson on Electricity.  
Wilson on the Skin.  
Walsh on the Lungs.











THE BORROWER WILL BE CHARGED  
AN OVERDUE FEE IF THIS BOOK IS  
NOT RETURNED TO THE LIBRARY ON  
OR BEFORE THE LAST DATE STAMPED  
BELOW. NON-RECEIPT OF OVERDUE  
NOTICES DOES NOT EXEMPT THE  
BORROWER FROM OVERDUE FEES.

Harvard College Widener Library  
Cambridge, MA 02138 (617) 495-2413

---

